UNCLASSIFIED

AD NUMBER

ADB031768

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Test Evalution; 10 Jul 1978. Other requests shall be referred to Air Force Flight Dynamics Laboratory Att: AFFDC/FXB; Wright-Patterson Air Force Base, OH 45433.

AUTHORITY

AFWAL ltr, 11 feb 1980

THIS PAGE IS UNCLASSIFIED

2 LEVEL III B031766

AFFDL-TR-78-91
Volume III

AD B031768

RAPID EVALUATION OF PROPULSION SYSTEM EFFECTS
Volume III—Derivative Procedure (DERIVP) Users Manual

T.E. Hickcox, R.A. Atkins, Jr., and W.H. Ball

BOEING AEROSPACE COMPANY
SEATTLE, WASHINGTON 98124

V. 2
B031766

JULY 1978

TECHNICAL REPORT AFFDL-TR-78-91, VOLUME III
Final Report for Period July 1977—July 1978

Distribution limited to U.S. Government agencies only; test and evaluation; statement applied 10 July 1978. Other requests for this document must be referred to the Air Force Flight Dynamics Laboratory (AFFDL/FXB), Wright-Patterson Air Force Base, Ohio 45433.

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

8 11 09 051

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This technical report has been reviewed and is approved for publication.

Gordon C. Tamplin

GORDON C. TAMPLIN
Project Engineer
Vehicle Synthesis Branch

R. L. Haas

RAYMOND L. HAAS
Chief, Vehicle Synthesis Branch
AF Flight Dynamics Laboratory

FOR THE COMMANDER

Melvin L. Buck

MELVIN L. BUCK
Acting Chief
Aeromechanics Division

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization, please notify AFFDL/FXB, W-PAFB, OH 45433 to help us maintain a current mailing list."

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19 REPORT DOCUMENTATION PAGE — READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 18 AFFDL-TR-78-91 - VOL-[redacted] 3	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 RAPID EVALUATION OF PROPULSION SYSTEM EFFECTS. VOLUME III. DERIVATIVE PROCEDURE (DERIVP) USERS MANUAL.	5. TYPE OF REPORT & PERIOD COVERED 9 FINAL rept. JUL[redacted]77-JUL[redacted]78
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 T. E. Hickcox, R. A. Atkins, Jr. [redacted] W. H. Ball	8. CONTRACT OR GRANT NUMBER(s) 15 F33615-77-C-3085
9. PERFORMING ORGANIZATION NAME AND ADDRESS Boeing Aerospace Company A Division of the Boeing Company Seattle, Washington 98124	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 2404121 17 01
11. CONTROLLING OFFICE NAME AND ADDRESS Vehicle Synthesis Branch (AFFDL/FXB) Air Force Flight Dynamics Laboratory Wright-Patterson AFB, Ohio 45433	12. REPORT DATE 11 JUL[redacted]78
	13. NUMBER OF PAGES 147
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 157p.	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Distribution limited to U.S. Government Agencies only;
Test and Evaluation; Statement applied 10 July 1978.
Other requests for this document must be referred to
Air Force Flight Dynamics Laboratory (AFFDL/FXB);
Wright-Patterson Air Force Base, Ohio 45433

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Installed engine performance
Inlet performance
Nozzle performance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This report presents the results of a research program to develop computerized preliminary analysis procedures for calculating propulsion system installation losses. These losses include inlet and nozzle internal losses and external drag losses for a wide variety of subsonic and supersonic aircraft configurations up to Mach 3.5. The calculation procedures used in the computer programs, which were largely developed from existing engineering procedures and experimental data, are suitable for preliminary studies of advanced aircraft configurations. Two interactive computer programs were developed during the

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

034 610 Gu

contract: (1) A propulsion installation effects program that calculates installed performance, using input maps of inlet and nozzle/aftbody characteristics for specific configurations, and (2) A derivative program that allows the user to generate new sets of input maps by perturbations to the geometries of the basic input maps. The work accomplished during the contract is documented in three separate volumes. Volume I is a Final Report discussing the analysis methods and data used to develop the programs, and major technical observations from the study. Volume II is a PIPSI Users Manual, containing documentation of the interactive propulsion installation program. Volume III is the Derivative Procedure Users Manual, documenting the methods and usage of the derivative procedure. Volume IV is a library of input maps.

FOREWORD

This report documents the work accomplished during USAF Contract No. F33615-77-C-3085. The work consisted of developing an interactive PIPSI computer program, developing an interactive derivative computer program, and developing and documenting supporting data libraries. The work was accomplished in three phases. As part of the work accomplished in Phase I of the contract, the interactive PIPSI program was completed and delivered to the Air Force. As part of Phase II work, derivative parameters were selected and development work was completed on the derivative program. During Phase III a library of inlet and nozzle/aftbody characteristics was prepared, test cases were completed, documentation was accomplished, and final programs were delivered to the Air Force. The program was conducted under the direction of the Vehicle Synthesis Branch, Air Force Flight Dynamics Laboratory, Air Force Systems Command. Mr. Gordon Tamplin was the Air Force Program Monitor.

The program was initiated on 17 July 1977 and draft copies of the final reports were submitted for approval on 15 May 1978.

Mr. W. H. Ball was Program Manager for The Boeing Company. The following individuals contributed significantly to the work accomplished during this contract: R. A. Atkins, Jr., computer programming; T. E. Hickcox, inlet derivative procedure development; E. J. Kowalski, inlet configurations and performance; and J. E. Petit and R. M. Trayler, nozzle/aftbody procedure and configurations.

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

LIST OF TABLES

LIST OF NOMENCLATURE AND SYMBOLS

A^*	Sonic area, in^2
A	Area, in^2
A_c	Inlet capture area, in^2
A_o	Local stream tube area ahead of the inlet, in^2
A_{o_I}	Free-stream tube area of air entering the inlet, in^2
$\mathcal{R}$	Aspect ratio, W_c/H_c for inlets, W_9/H_9 for nozzles, dimensionless
C_D	Drag coefficient, $\frac{D}{q A_{ref.}}$, dimensionless
C	Sonic velocity; ft/sec.
C-D	Convergent-divergent
$C_{D_{ADD}}$	Additive drag coefficient, $C_{D_{ADD}} = \frac{D_{ADD}}{q A_c}$, dimensionless
$C_{D_{A10}}$, $C_{D_{AB}}$	Afterbody drag coefficient, $\frac{DRAG}{q A_{10}}$, dimensionless
$C_{D_{Base}}$	Base drag coefficient $\frac{(P_b - P_\infty) A_{base}}{q A_{10}}$, dimensionless
$C_{D_{A10-A9}}$,	
$C_{D_{PAP}}$	Drag coefficient, $\frac{D}{q_o (A_{10} - A_9)}$, based on projected area, dimensionless
C_{D_S}	Scrubbing drag coefficient, $\frac{DRAG}{q A_{10}}$, dimensionless
C_{f_G}	Thrust coefficient, $\frac{F_g}{\frac{w}{g}(V_i)}$ dimensionless
C_V	Nozzle velocity coefficient, dimensionless
Conv.	Convergent

D	Drag, lb.; Hydraulic Diameter, $\frac{4A}{P}$, in., diameter, in.
F	Thrust, lb.
F_N	Net thrust, lb.
F_{N_A}	Installed net thrust, lb.
F_{g_i}	Ideal gross thrust (fully expanded), lb.
f/a	Fuel/air ratio, dimensionless
g	Gravitational constant, ft/sec^2
h	Enthalpy per unit mass, BTU/lb.; height, in.
h_{fan}	Enthalpy of fan discharge flow, BTU/lb
h_{pri}	Enthalpy of primary exhaust flow after heat addition, BTU/lb
h_t	Throat height, in^2
IMS_T	Integral mean slope parameter, truncated $IMS_T = -\frac{1}{(1 - A_9/A_{10})} \int_{A_9/A_{10}}^{1.0} \frac{d(A/A_{10})}{d(L/D_{eq})} \, d(A/A_{10})$
L	Length, in.
M	Mach number, dimensionless
P	Static pressure, lb/in^2, perimeter, in.
P_r	Relative pressure,; the ratio of the pressures p_a and p_b corresponding to the temperatures T_a and T_b, respectively, along a given isentrope, dimensionless
P.S.	Power setting
P_T	Total pressure, lb/in2
Q	Effective heating value of fuel, BTU/lb.

q	Dynamic pressure, lb/in^2
R	Gas constant
R, r	Radius, in.
R_F	Total pressure recovery
SFC	Specific fuel consumption
SFC_A	Installed specific fuel consumption
T	Temperature, ^oR
V	Velocity, ft/sec
W	Mass flow, lb/sec
W_{BX}	Bleed air removed from engine, lb/sec.
W_C.	Corrected airflow, lb/sec. $\frac{W\sqrt{\theta}}{\delta}$
W_f	Weight flow rate of fuel, lb/sec.
W_2	Weight flow rate of air, primary plus secondary, lb/sec.
W_8	Primary nozzle airflow rate, lb/sec.
x	Length, in.
α	Angle of attack; convergence angle of nozzle, degrees
γ	Ratio of specific heats, dimensionless
δ_{T_2}	Pressure correction factor, P_{T_2}/P_{STD}.
ϵ	Diffuser loss coefficient, $\frac{\Delta P_T}{q}$, dimensionless
θ_{T_2}	Temperature correction factor, T_{T_2}/T_{STD}.

θ_N	2-D Nozzle wedge half-angle
θ_P	Round Plug nozzle half-angle
η_B	Burner efficiency, dimensionless
ν	Kinematic viscosity, $ft^2/sec.$
ρ	Density, lb/ft^3

SUBSCRIPTS

amb	Ambient
AB	Afterbody
B	Burner
B_X	Bleed airflow extracted from the engine
b, base	Base flow region
BP	Bypass
BLC	Boundary layer bleed
btail	Boattail

SECTION I
INTRODUCTION

The purpose of the derivative procedure is to provide a first-order analytical method to determine the effects on inlet and nozzle performance of configuration differences from the nearest configuration represented in the library of stored maps (which are built-up for specific configurations). The derivative process is illustrated in Figure 1.

The derivative procedure utilizes analytical and experimental data in determining changes in the stored performance maps that result from geometric changes in the inlet and nozzle/aftbody configurations. The analytical procedures and experimental data have been used to develop an interactive computer program that allows the user to interactively account for changes to the configurations in the library. The program then generates new input data maps in the PIPSI format that represent the performance characteristics of the perturbed configuration. An overlay structure was used to construct the program as shown in Figure 2.

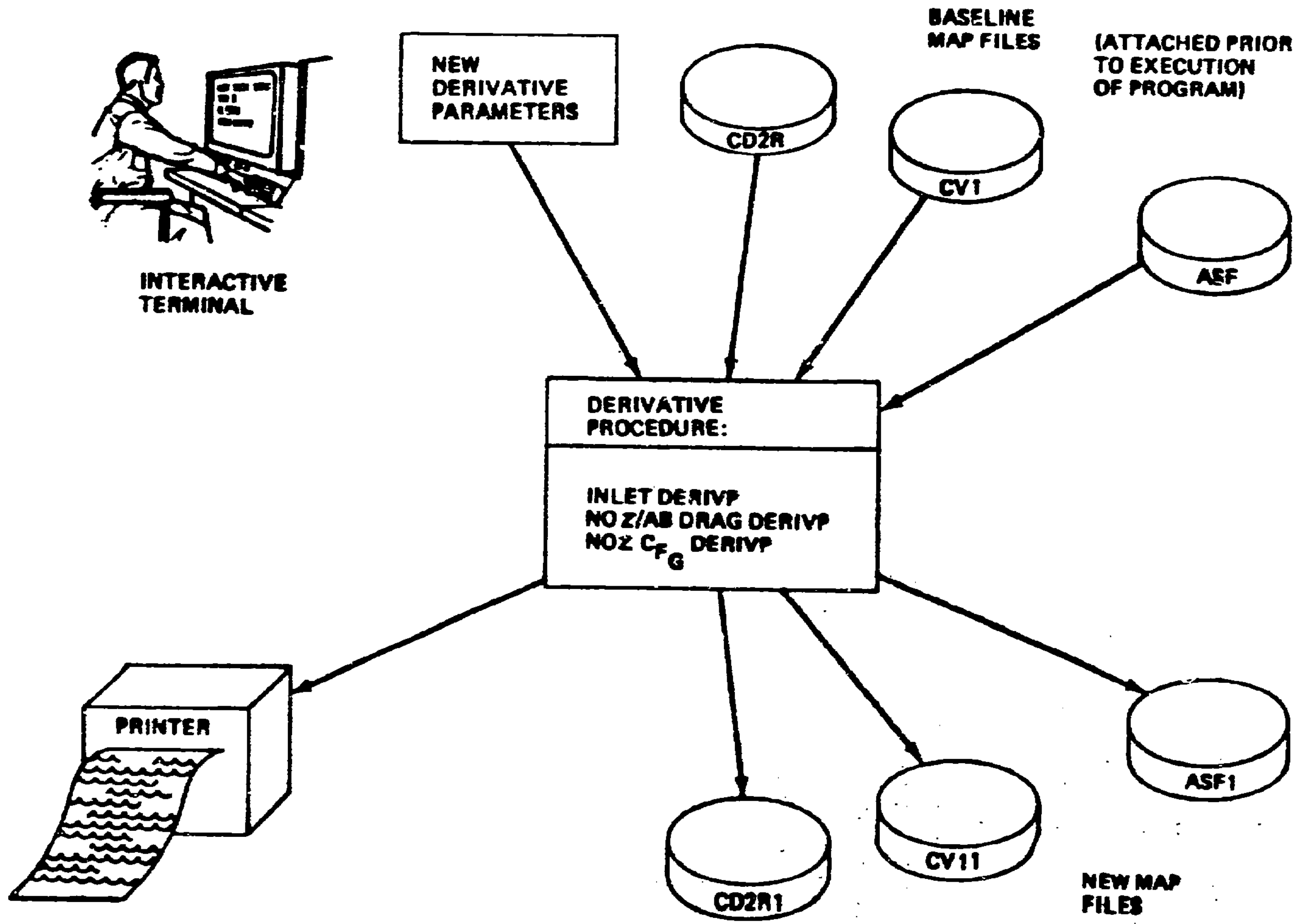


Figure 1. The Derivative Process

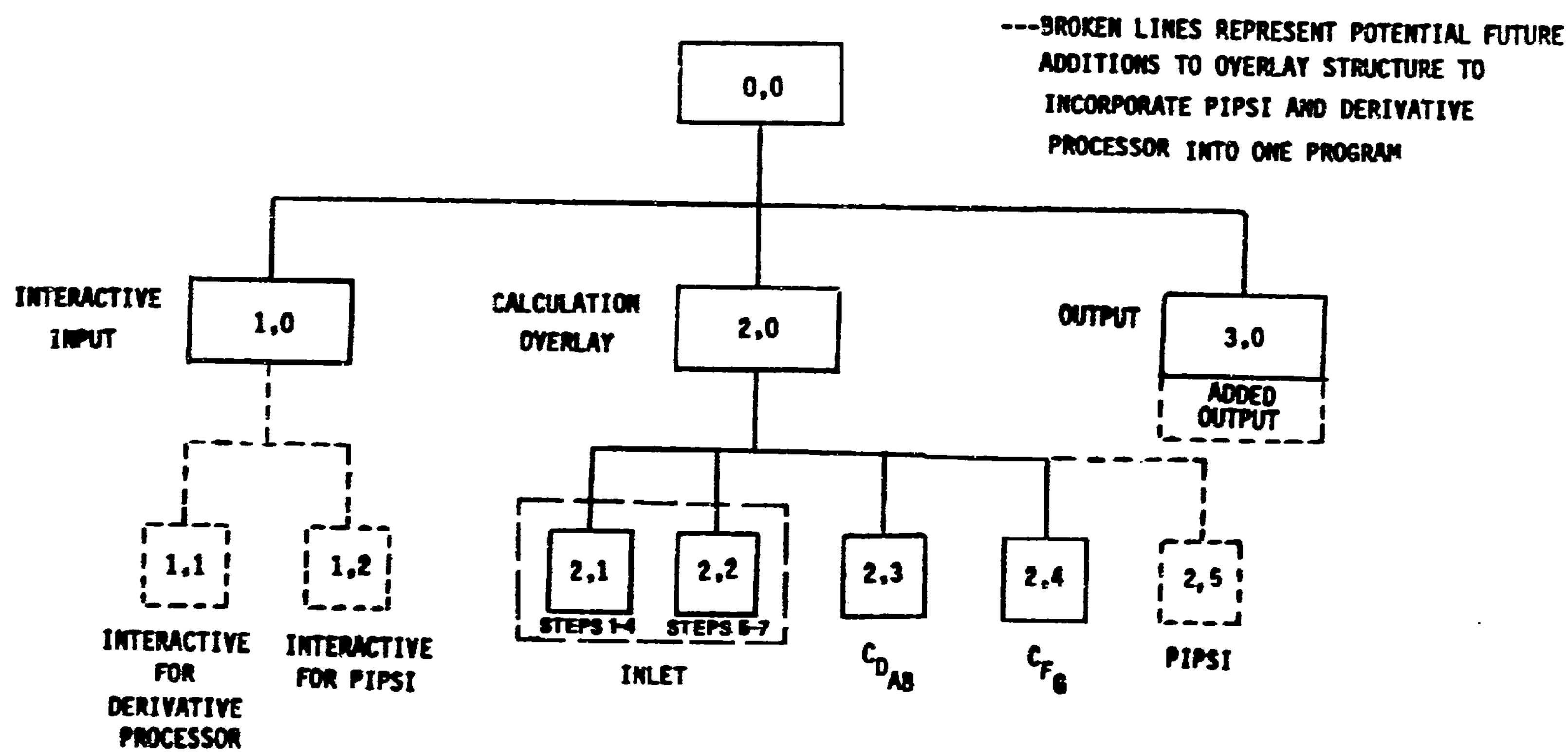


Figure 2. Derivative Procedure Overlay Structure

SECTION II
DERIVATIVE PARAMETERS

The first step in the development of the derivative procedure was the selection of the derivative parameters. The derivative parameters are those parameters that will be perturbed to produce a new set of performance characteristics from an existing (or "baseline") set of maps.

The criteria used to select the derivative parameters were:

1) Variations in the parameter must have a significant effect on the content of the maps used to describe inlet or nozzle/aftbody performance. The derivative procedure will be used as part of an overall preliminary analysis procedure for calculating first-order propulsion system installation effects. It should not be used for detailed design studies because the methodology employed in developing the input data for the inlet and nozzle maps, of necessity, requires using a variety of engineering analyses, test data and assumptions based on experience and judgment. The methods employed are believed to be reasonable; however, the procedure may not be sensitive to the effects of small variations in some design variables. The user should ascertain whether or not the procedure will properly evaluate the desired parameter before using the procedure. The derivative parameters selected for the present procedure are those which have been clearly identified by test or analysis as having "first-order" effects on installed performance.

2) To the maximum extent possible, an attempt was made to define the derivative parameters in terms of geometric variables that can be easily related to the airplane configuration. This was done to help in evaluating the effects of configuration changes on installed performance.

3) Derivative parameters had to represent trends that were strong enough to be clearly evident in spite of the scatter in test data obtained from typical inlet and nozzle tests.

Table I presents a list of the derivative parameters that have been selected for use in the derivative procedures. The definition of each of these parameters is included. Tables II and III present the derivative parameters and the performance map variables that they affect, either directly or indirectly.

TABLE I

DERIVATIVE PARAMETERS AND THEIR DEFINITIONS

1) Aspect Ratio (AR)	-	Applicable to two-dimensional inlets only
	-	Defined as inlet width divided by inlet lip height (relative to tip position).
2) Sideplate Cutback (SPC)	-	Applicable to two-dimensional inlets only
	-	Defined as the percent of a full sideplate area that is removed to define a partial sideplate.
		The upper edge of a full sideplate extends from the ramp tip to the cowl lip.
3) First Ramp or Cone Angle	-	Applicable to two-dimensional and axisymmetric inlets
	-	Defined as surface ramp angle, in degrees, relative to horizontal reference line for two-dimensional inlets
		Defined as cone surface angle, in degrees, relative to inlet centerline for axisymmetric inlets (cone half-angle)

TABLE I (Continued)

4)	Design Mach Number (M_o Design)	- Applicable to all inlets - Defined as the maximum Mach number at which the inlet is designed to operate
5)	Cowl Lip Bluntness	- Applicable to all inlets Defined as the inlet lip surface radius divided by the lip height.
6)	Takeoff Door Area	- Applicable to all inlets - Defined as the total door throat area for the takeoff auxiliary air system divided by the inlet capture area
7)	External Cowl Angle	- Applicable to all inlets Defined as external cowl surface angle, in degrees, relative to inlet horizontal reference line
8)	Exit Nozzle Type for Bleed	- Applicable to two-dimensional and axisymmetric inlets - Defines whether bleed exit nozzle is convergent or convergent-divergent
9)	Exit Nozzle Angle for Bleed	- Applicable to two-dimensional and axisymmetric inlets - Defined as bleed exit nozzle angle, in degrees, relative to inlet horizontal reference line

TABLE I (Continued)

10) Exit Flap Aspect Ratio for Bleed (AR_F)	-	Applicable to two-dimensional and axisymmetric inlets
	-	Defined as flap width divided by flap length
11) Exit Flap Area for Bleed (A_F/A_C)	-	Applicable to two-dimensional and axisymmetric inlets
	-	Defined as flap area divided by inlet capture area
12) Exit Nozzle Type for Bypass	-	Applicable to all inlets
	-	defines whether bypass exit nozzle is convergent or convergent-divergent
13) Exit Nozzle Angle for Bypass	-	Applicable to all inlets
	-	Defined as bypass exit nozzle angle, in degrees, relative to inlet horizontal reference line
14) Exit Flap Aspect Ratio for Bypass (AR_F)	-	Applicable to all inlets
	-	Defined as flap width divided by flap length
15) Exit Flap Area for Bypass (A_F/A_C)	-	Applicable to all inlets
	-	Defined as flap area divided by inlet capture area
16) Subsonic Diffuser Area Ratio (A_2/A_1)	-	Applicable to all inlets
	-	Defined as exit area (compressor face) divided by entrance area (throat)

TABLE I (Continued)

17) Subsonic Diffuser Total Wall Angle	-	Applicable to all inlets
	-	Defined as the total equivalent wall divergence angle, from entrance to exit
18) Subsonic Diffuser Loss Coefficient (ϵ)	-	Applicable to all inlets
	-	Defined by the equation $P_{T_2}/P_{T_1} = 1.0 - \epsilon \left[1 - \frac{1}{(1 + 0.2M^2)^{3.5}} \right]$
19) Throat to Capture Area Ratio (A_T/A_C)	-	Applicable to Pitot inlets only
	-	Defined as the fixed throat area divided by the inlet capture area Note: If this parameter is altered and the subsonic diffuser area ratio is not, the compressor face area is scaled with throat area at a fixed capture (lip) area.
20) Nozzle/Aftbody Area Distribution	-	Applicable to all nozzle/aftbodies. Defined by the cross-sectional area distribution as a function of station from A_{10} (ref. area) to A_9 (nozzle exit area). Characterized by the parameter IMS_T.
21) Radial Tail Orientation Position	-	Applicable to all nozzle/aftbodies with tails. Defined by the angular orientation of the tail mounting location relative to the vertical position.

TABLE I (Concluded)

22) Fore-and-aft Tail Location	-	Applicable to all nozzle/aftbodies with tails. Defined by the location of the aft point of the tail/aftbody junction relative to the aftbody length ($X_{A_{10}} - X_{A_9}$).
23) Base Area	-	Applicable to all nozzle/aftbodies with base area. Defined by the ratio of the base area, A_{BASE}, to the aftbody reference area, A_{10}.
24) Plug Half Angle	-	Applicable to round plug nozzles. Defined as the half-angle of the plug centerbody measured relative to the plug axial centerline.
25) Ramp Half Angle	-	Applicable to two-dimensional wedge nozzles. Defined by the wedge half-angle relative to the wedge centerline.
26) Aspect Ratio (W_9/H_9)	-	Applicable to two-dimensional nozzles, both C-D and wedge types. Defined by the ratio of nozzle width to height at the nozzle exit station.
27) Divergence Half-Angle (θ_{DIV})	-	Applicable to convergent-divergent round and 2-D nozzles. Defined as the angle of the diverging section nozzle wall relative to the axial centerline of the nozzle.

TABLE II INLET DERIVATIVE PROCEDURE CROSS-REFERENCE
(DIRECT AND INDIRECT EFFECTS)

	DERIVATIVE PARAMETER	PROGRAM STEP 1	2	3	4	5	6	7
		A_{OI}/A_C	$A_{O_{BLC}}/A_C$	A_O/A_C	P_{T_2}/P_{T_0}	$C_{D_{SPILL}}$	$C_{D_{BLC}}$	$C_{D_{BYP}}$
1	ASPECT RATIO (FOR 2-D INLETS)	●	●	●	●	●	●	●
2	SIDEPLATE CUTBACK (FOR 2-D INLETS)	●	●	●	●	●	●	●
3	FIRST RAMP (CONE) ANGLE	●	●	●	●	●	●	●
4	DESIGN MACH NUMBER	●	●	●	●	●	●	●
5	COWL LIP BLUNTNESS	●		●	●			●
6	TAKEOFF DOOR AREA	●		●	●			●
7	EXTERNAL COWL ANGLE					●		
8	EXIT NOZZLE TYPE FOR BLEED						●	
9	EXIT NOZZLE ANGLE FOR BLEED						●	
10	EXIT FLAP ASPECT RATIO FOR BLEED						●	
11	EXIT FLAP AREA FOR BLEED						●	
12	EXIT NOZZLE TYPE FOR BYPASS							●
13	EXIT NOZZLE ANGLE FOR BYPASS							●
14	EXIT FLAP ASPECT RATIO FOR BYPASS							●
15	EXIT FLAP AREA FOR BYPASS							●
16	SUBSONIC DIFFUSER AREA RATIO	●		●	●			●
17	SUBSONIC DIFFUSER TOTAL WALL ANGLE	●		●	●			●
18	SUBSONIC DIFFUSER LOSS COEFFICIENT	●		●	●			●
19	THROAT/CAPTURE AREA RATIO (FOR PITOT INLETS)	●		●				

TABLE III NOZZLE/AFTBODY DERIVATIVE PROCEDURE REFERENCE LIST

DERIVATIVE PARAMETER	PROGRAM STEP	
	NOZZLE/AFTBODY DRAG CALCULATION	GROSS THRUST COEFFICIENT CALCULATION
AFT-END CLOSURE (INCLUDES EFFECT OF ASPECT RATIO, BOAT-TAIL ANGLE, TWIN NOZZLE SPACING	●	
RADIAL TAIL ORIENTATION	●	
FORE- AND -AFT TAIL LOCATION	●	
BASE AREA	●	
DIVERGENCE HALF-ANGLE (FOR AXI-SYMMETRIC AND 2-D C-D NOZZLES		●
AXISYMMETRIC PLUG HALF-ANGLE		●
ASPECT RATIO (FOR 2-D C-D AND 2-D WEDGE NOZZLES)		●
WEDGE HALF-ANGLE (FOR 2-D WEDGE NOZZLES)		●

SECTION III
ENGINEERING DESCRIPTION OF DERIVATIVE PROCEDURE

3.1 INLET DERIVATIVE PROCEDURE

The purpose of the inlet derivative procedure is to analytically modify a baseline inlet configuration and define the resulting performance characteristics in a format that can be used as direct input to the PIPSI program. Baseline inlet geometry and performance characteristics will be represented by elements of a set of inlet geometries and performance characteristics contained in the library of map files. The inlet geometric characteristics represented by the inlet configurations contained in the basic library of inlet maps are shown in Table IV. The derivative procedure provides a first-order prediction of the new inlet performance based on the baseline map file and changes in derivative parameters from those of the baseline inlet.

This procedure is based on two key assumptions:

(1) Generally applicable functions exist which relate changes in inlet performance characteristics to changes in inlet design parameters; and

(2) The derivative procedure will not alter the sophistication, technology, design philosophy, or mission related design trades that are represented by the baseline inlet. As a result, the inlet level of technology, type of application, complexity and design philosophy are removed as variables in the derivative procedure. It is important to note that as a result of this approach, a new inlet with given design variables will not have completely unique performance characteristics if it is generated by perturbations from different baseline map files. Each result will reflect the design of the chosen baseline inlet.

TABLE IV SUMMARY OF INLET CONFIGURATIONS AND DERIVATIVE PARAMETERS

DERIVATIVE PARAMETERS	DEFINITION	CONFIGURATION NUMBERS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Inlet Aspect Ratio	W_c/h_c	N/A	N/A	N/A	N/A	N/A	N/A	2.0	1.0	1.0	N/A	N/A	N/A	1.0	1.0	1.0	N/A	N/A	N/A
2 Sideplate Cutback	A_{cB}/A_{sp}	N/A	N/A	N/A	N/A	N/A	N/A	.75	.20	.25	N/A	N/A	N/A	0.0	0.0	0.0	N/A	N/A	N/A
3 First Ramp Angle	Deg.	N/A	N/A	N/A	N/A	N/A	N/A	7.0	7.3	6.0	26.0	22.0	18.0	7.0	7.0	7.0	10.4	10.0	10.0
4 Design Mach Number	~	.90	1.60	.90	.90	1.50	1.60	1.60	2.0	2.5	1.60	2.8	2.5	2.6	3.0	3.5	2.35	3.0	3.5
5 Cowl Lip Bluntness	R_{lip}/h_c	.03	.02	.030	.022	.022	0.	.012	.012	.008	.02	.015	.015	0.	0.	0.	0.	0.	0.
6 Takeoff Door Area	A_{to}/A_c	0.0	0.0	N/A	.020	.18	.22	.236	.20	.11	.482	.46	.26	.12	.30	.20	.20	.20	.20
7 External Cowl Angle	Deg.	4.5	2.5	12.	17.	5.0	5.0	13.0	17.5	17.0	16.	19.	12.	12.	12.	18.0	1.0	0.0	2.0
8 Bleed Exit Nozzle Type	Conv. or C-D	N/A	N/A	N/A	N/A	N/A	N/A	Conv.	Conv.	Conv.	N/A	Conv.	Conv.	Conv.	Conv.	Conv.	Conv.	Conv.	Conv.
9 Bleed Exit Nozzle Angle	Deg.	N/A	N/A	N/A	N/A	N/A	N/A	20.0	15.0	20.0	N/A	20.0	15.	20.0	0.0	15.	15.	15.	10.
10 Bleed Exit Flap Aspect Ratio	W_f/h_f	N/A	N/A	N/A	N/A	N/A	N/A	1.0	2.0	.80	N/A	1.0	1.0	.80	N/A	1.0	1.0	1.0	1.0
11 Bleed Exit Flap Area	A_f/A_c	N/A	N/A	N/A	N/A	N/A	N/A	.10	.10	.50	N/A	.10	.10	.20	N/A	.20	.20	.20	.20
12 Bypass Exit Nozzle Type	Conv. or C-D	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Conv.	C-D	N/A	Conv.	Conv.	C–D	C–D	C–D	C–D	C–D	C–D
13 Bypass Exit Nozzle Angle	Deg.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.0	20.	N/A	20.	15.	20.	15.	15.	15.	15.	10.
14 Bypass Exit Flap Aspect Ratio.	W_f/h_f	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.0	.67	N/A	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0
15 Bypass Exit Flap Area	A_f/A_c	N/A	N/A	N/A	N/A	N/A	N/A	N/A	.20	.208	N/A	.20	.20	.20	.20	.20	.20	.20	.20
16 Subsonic Diffuser Area Ratio	A_2/A_1	1.40	1.40	1.25	1.25	1.308	1.306	1.373	1.90	1.89	1.44	1.83	2.6	1.40	2.0	4.7	1.57	2.1	4.97
17 Diffuser Total Wall Angle	Deg.	2.5	3.5	12.0	12.0	4.0	4.0	8.0	10.0	8.5	6.0	9.0	15.3	8.0	12.0	11.5	7.0	12.0	9.0
18 Subsonic Diffuser Loss Coefficient	ϵ	.12	.12	.015	.015	.12	.12	.12	.12	.16	.08	.12	.14	.14	.12	.14	.08	.12	.12
19 Throat/Capture Area Ratio	A_T/A_c	N/A	N/A	.80	.90	.90	1.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
INLET TYPE		Chin	Chin	Pitot	Pitot	Pitot (N.S.)	Pitot (N.S.)	E.C. 2-D	E.C. 2-D	E.C. 2-D	E.C. AXI	E.C. AXI	E.C. AXI	M.C. 2-D	M.C. 2-D	M.C. 2-D	M.C. AXI	M.C. AXI	M.C. AXI
FILE NAME		A7	F8	MSSUB	MSSUB	NS	NS2	LWF	ATS2	ASF	VSTOL	NVSTO	TM183	F8	INT	M3520	AST	NASA3	BCAC35

Simplified flow charts are included that provide a basic outline of the procedure and each of its steps. The seven basic steps in the procedure (Figure 3) are ordered in a manner which provides a sequential definition of the new performance maps without the requirement of iteration between later and early steps. A summary of these steps is as follows:

STEP 1

The effect of geometry modification on inlet capture is determined for two-dimensional inlets from the Petersen-Tamplin analysis using a single ramp inlet approximation. For axisymmetric inlets the effects of inlet modification are determined from a single cone analysis. The effect of design Mach number for both these inlet types alters the Mach 1.0 inlet captured mass flow ratio, A_{O_I}/A_C, and provides a correction over the supersonic and subsonic Mach number range. For supersonic pitot type inlets, the effect of a change in design Mach number on inlet captured mass flow ratio is calculated using the assumption of fixed throat to lip area ratio.

STEP 2

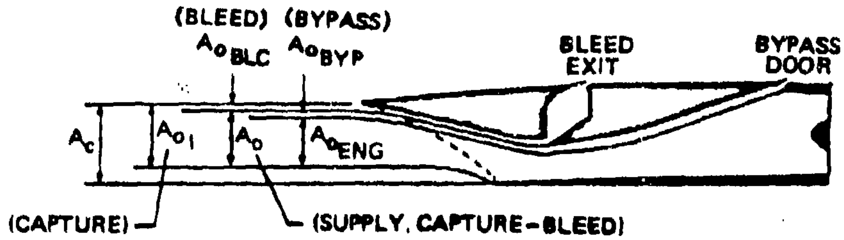
Changes in bleed mass flow caused by design modifications are calculated by accounting for the effects of altered geometry on surface wetted-area ratio and changes in inlet pressure gradient.

STEP 3

"Engine-plus-bypass" supply mass flow ratio, A_O/A_C, is determined simply by reducing the inlet captured mass flow ratio, A_{O_I}/A_C, by the required bleed mass flow ratio, $A_{O_{BLC}}/A_C$.

STEP 4

Changes in inlet recovery due to geometry modifications are determined from changes in shock losses and subsonic diffuser recovery. The effect of design Mach number change on recovery is determined from the use of the loss coefficient, $\frac{\Delta P_I}{P_T}/q_o$, at equivalent Mach numbers.



Step 1	Calculate effect of geometry modification and design mach number on inlet mass flow ratio, A_{O_I}/A_C.
Step 2	Calculate effect on boundary layer bleed mass flow ratio, $A_{O_{BLC}}/A_C$, due to geometry modifications and changes in pressure gradients.
Step 3	Calculate new inlet supply, A_O/A_C, from new A_{O_I}/A_C and $A_{O_{BLC}}/A_C$.
Step 4	Calculate effect on inlet recovery due to geometry modifications, design mach number, and subsonic diffuser efficiency.
Step 5	Calculate effect on spillage drag, $C_{D_{SPILL}}$, of geometric modifications and design mach number.
Step 6	Calculate effect on bleed drag, $C_{D_{BLC}}$, of geometric modifications and changes in design mach number.
Step 7	Calculate effect on bypass drag, $C_{D_{BYP}}$, of geometric modifications and changes in design mach number.

Figure 3. Inlet Derivative Procedure Flow Chart

STEP 5
The changes in spillage drag due to design modifications are calculated in a manner similar to the inlet capture mass flow ratio by determining the design change effect for a single ramp or single cone inlet.

STEPS 6 and 7
Changes in bleed and bypass drag due to design modifications are determined by recalculation of the bleed and bypass system drag.

Any step in this process may depend on a previous step, but does not depend on any following step, thereby allowing a non-iterative procedure. Table V summarizes some of the main sources of data and methods used in the inlet derivative procedure.

3.2 NOZZLE/AFTBODY DERIVATIVE PROCEDURE

A nozzle/aftbody drag calculation procedure has been formulated which performs two functions:

(1) It calculates nozzle/aftbody drag as a function of aft-end closure effects (area distribution will be used as input to reflect the effects of aspect ratio, boattail shape, and twin nozzle spacing), tail position (radial orientation and axial location), and base area.

(2) Revised nozzle/aftbody drag maps are generated which incorporate the effects of perturbations in nozzle/aftbody geometry on drag. Flow charts showing the major steps in the nozzle/aftbody calculation procedure are presented in Section VI.

The drag calculation procedure begins with an input cross-sectional area distribution for the aftbody from which the IMS_T parameter is calculated for this area distribution. The IMS_T value is used as input

TABLE V INLET DERIVATIVE PROCEDURE DATA SOURCES

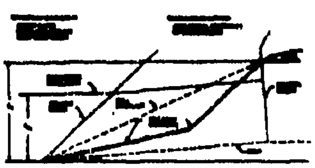
	PARAMETER	SOURCE OF DATA	EXAMPLE
1.	ASPECT RATIO (FOR 2-D INLETS)	ANALYTICAL CALCULATION USING METHODS OF AFAPL-TR-66-30 CHANGES IN ASPECT RATIO AFFECT: 1. $A_{0_{BLC}}/A_C$ (WETTED AREA) 2. A_{0_I}/A_C 3. P_{T2}/P_{T_0} 4. ADDITIVE DRAG	
2.	SIDEPLATE CUTBACK (FOR 2-D INLETS)	ANALYTICAL CALCULATION USING METHODS OF AFAPL-TR-66-30 (SAME AS ABOVE)	
3.	FIRST RAMP ANGLE (2-D INLETS)	ANALYTICAL CALCULATION USING METHODS OF AFAPL-TR-66-30	
	FIRST CONE ANGLE (AXISYMMETRIC INLETS)	ANALYTICAL CALCULATION USING AN AXISYMMETRIC CALCULATION PROCEDURE SIMILAR TO 2-D PROCEDURE ABOVE. AFFECTS: 1. $A_{0_{BLC}}/A_C$ 2. A_{0_I}/A_C 3. P_{T2}/P_{T_0}	

TABLE V INLET DERIVATIVE PROCEDURE DATA SOURCES (cont.)

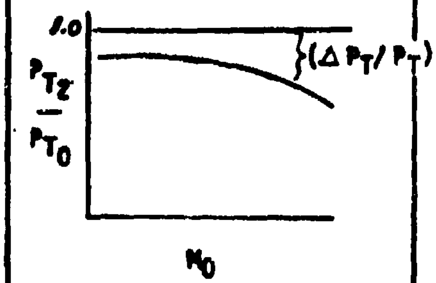
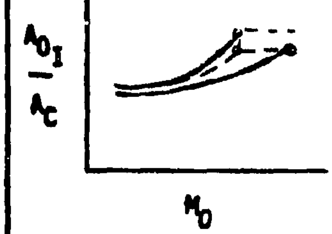
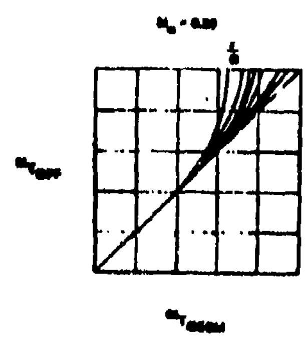
	PARAMETER	SOURCE OF DATA	EXAMPLE
4.	DESIGN MACH NUMBER	MACH NUMBER EQUIVALENCE RELATIONSHIPS. $A_{0_{BLC}}/A_C$ CHANGES BECAUSE PRESSURE GRADIENT CHANGES. P_{T2}/P_{T_0} CHANGES BECAUSE TIP SHOCK LOSS CHANGES AT $M_{0_{DES}}$. A_{0_I}/A_C CHANGES BECAUSE SONIC MASS FLOW CAPABILITY GOES DOWN AS M_0 INCREASES. MAX OBTAINABLE THROAT AREA RATIO, A_T/A_C, TYPICALLY IS SMALLER AS M_0 INCREASES.	 GEOMETRIC CHANGES FIRST THEN MACH NUMBER EFFECTS 
5.	COWL LIP BLUNTNESS	LOW-SPEED PROCEDURE DOCUMENTED IN AFFDL-TR-72-147.	

TABLE V INLET DERIVATIVE PROCEDURE DATA SOURCES (cont.)

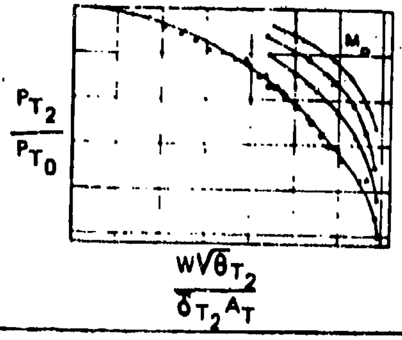
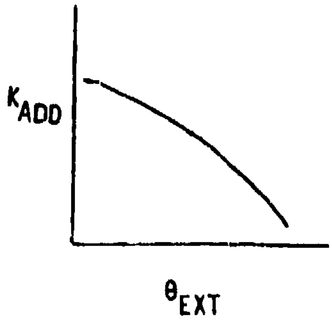
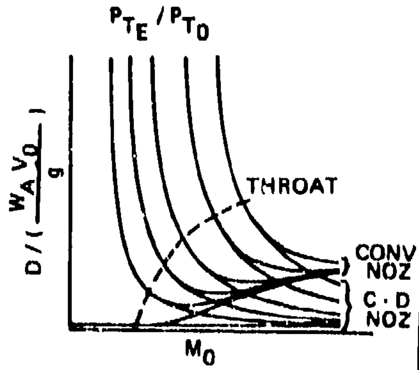
	PARAMETER	SOURCE OF DATA	EXAMPLE
6.	TAKEOFF DOOR AREA	LOW-SPEED PROCEDURE DOCUMENTED IN AFFDL-TR-72-147	
7.	EXTERNAL COWL ANGLE	CORRELATION DEVELOPED FROM EXPERIMENTAL DATA THAT RELATE EXTERNAL COWL ANGLE TO K_{ADD}	
8.	EXIT NOZZLE TYPE (FOR BLEED)	NOZZLE CAN BE EITHER CONVERGENT OR CONVERGENT/DIVERGENT USED IN MOMENTUM DRAG CALCULATION ANALYTICAL METHODS DOCUMENTED IN AFFDL-TR-72-147 AND PITAP BLEED RECOVERY	
9.	EXIT NOZZLE ANGLE FOR BLEED	USER CAN SELECT NOZZLE EXIT ANGLE FOR MOMENTUM DRAG CALCULATION ANALYTICAL METHODS DOCUMENTED IN AFFDL-TR-72-147	

TABLE V INLET DERIVATIVE PROCEDURE DATA SOURCES (cont.)

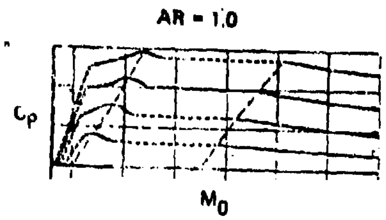
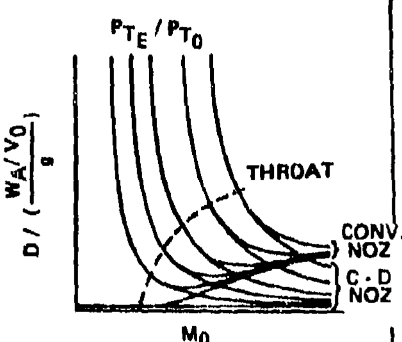
	PARAMETER	SOURCE OF DATA	EXAMPLE
10	EXIT FLAP ASPECT RATIO FOR BLEED	FLAP ASPECT RATIO IS A USER INPUT AND IS USED TO CALCULATE FLAP DRAG. FLAP DRAG IS CALCULATED BY METHODS DOCUMENTED IN AFFDL-TR-72-147	
11	EXIT FLAP AREA FOR BLEED	FLAP AREA IS A USER INPUT AND IT IS USED TO CALCULATE FLAP DRAG. FLAP DRAG CALCULATION METHODS ARE DOCUMENTED IN AFFDL-TR-72-147	$C_D = C_P \frac{(A_F)(\sin \theta_E)}{(A_C)}$
12	EXIT NOZZLE TYPE FOR BYPASS	NOZZLE TYPE CAN BE EITHER CONVERGENT OR C-D. USED IN MOMENTUM DRAG CALCULATION. ANALYTICAL METHODS DOCUMENTED IN AFFDL-TR-72-147	
13.	EXIT NOZZLE ANGLE FOR BYPASS	USER CAN SELECT NOZZLE EXIT ANGLE USED IN MOMENTUM DRAG CALCULATION ANALYTICAL METHODS DOCUMENTED IN AFFDL-TR-72-147	

TABLE V INLET DERIVATIVE PROCEDURE DATA SOURCES (cont.)

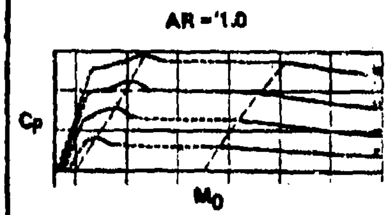
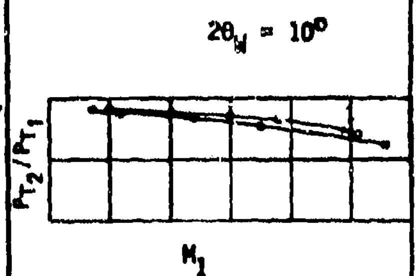
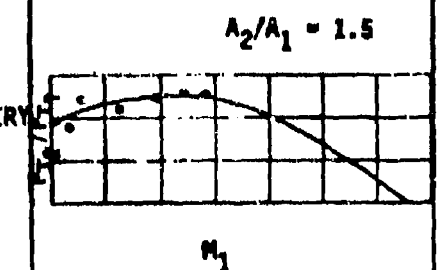
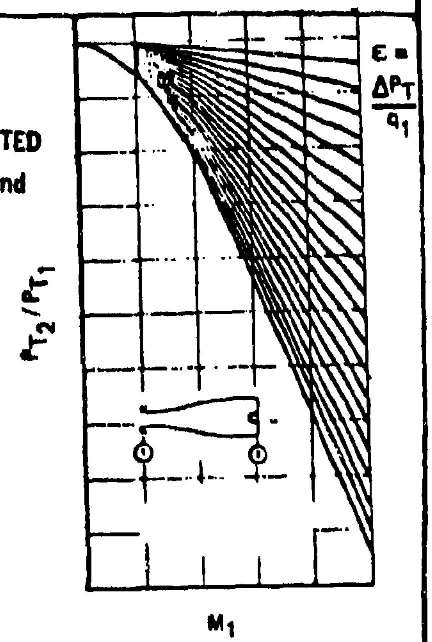
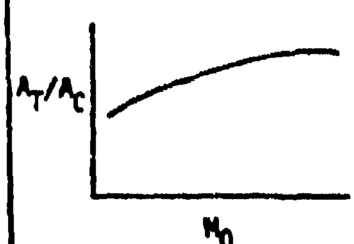
	PARAMETER	SOURCE OF DATA	EXAMPLE
14.	EXIT FLAP ASPECT RATIO FOR BYPASS	FLAP ASPECT RATIO IS A USER INPUT USED TO CALCULATE FLAP DRAG. FLAP DRAG IS CALCULATED BY METHODS DOCUMENTED IN AFFDL-TR-72-147.	
15.	EXIT FLAP AREA FOR BYPASS	EXIT FLAP AREA IS INPUT BY USER. FLAP AREA IS USED IN FLAP DRAG CALCULATION. CALCULATION METHODS ARE DOCUMENTED IN AFFDL-TR-72-147.	$C_D = C_p \frac{A_F}{A_C} (\sin \theta_E)$
16.	SUBSONIC DIFFUSER AREA RATIO	SUBSONIC DIFFUSER DATA CORRELATIONS RELATING DIFFUSER TOTAL PRESSURE RECOVERY TO DIFFUSER AREA RATIO. DATA SOURCES: NWCTP5555, AFFDL-TR-69-21, RM L56F05.	
17.	SUBSONIC DIFFUSER TOTAL WALL ANGLE	SUBSONIC DIFFUSER DATA CORRELATIONS RELATING DIFFUSER TOTAL PRESSURE RECOVERY TO DIFFUSER TOTAL WALL ANGLE. DATA SOURCES: NWCTP5555 AFFDL-TR-69-21, RM L56F05.	

TABLE V INLET DERIVATIVE PROCEDURE DATA SOURCES (concluded)

	PARAMETER	SOURCE OF DATA	EXAMPLE
18.	SUBSONIC DIFFUSER LOSS COEFFICIENT	DIFFUSER LOSS COEFFICIENT IS AN OPTIONAL INPUT BY THE USER. DIFFUSER RECOVERY IS THEN CALCULATED BY AN EQUATION RELATING ϵ, M_1, and P_{T_2}/P_{T_1} $P_{T_2}/P_{T_1} = 1 - \epsilon\left(1 - \frac{1}{(1 + .2M_1^2)^{3.5}}\right)$	
19.	A_T/A_C (FOR PITOT INLETS ONLY)	INPUT A_T/A_C IF DIFFERENT FROM LIBRARY VALUE USER MUST CONSIDER EFFECT OF AREA RATIO ON INLET CAPTURE, SINCE THE INLET THROAT MACH NUMBER IS HELD CONSTANT	

to data correlations which provide nozzle/aftbody drag as a function of IMS_T, Mach number, and exhaust nozzle exit static pressure ratio. Data correlations based on IMS_T parameters are available for certain classes of installations, namely:

(1) Single, isolated axisymmetric configurations
(2) Twin axisymmetric configurations
(3) Single 2-D wedge nozzle configurations
(4) Twin 2-D wedge nozzle configurations

The data correlations listed above are used to predict drag of similar configurations within the limitations of the data correlations. Input requirements must be fairly detailed because an accurate cross-sectional area distribution must be available as input to compute the IMS_T parameter.

After obtaining the basic nozzle/aftbody drag from the IMS_T correlations, drag corrections are added to account for the radial orientation of tails, longitudinal location of tails, and base drag. The total drag is then calculated as the sum of the individual drag contributions. The drag calculation process is repeated for both the old (baseline) configuration and the new (perturbed) configuration. The incremental drag difference is then added to the old (baseline) drag map to produce a new drag map for the new (perturbed) configuration.

3.3 NOZZLE GROSS THRUST COEFFICIENT DERIVATIVE PROCEDURE

Using the calculation procedure built into this program, incremental changes in nozzle geometric variables are made by the user and the resulting changes in C_{F_G} are calculated. The program then adds the incremental changes in nozzle C_{F_G} to the old (baseline) C_{F_G} map to obtain the C_{F_G} map for the new configuration.

The calculation methods used to determine the effects on nozzle gross thrust coefficient (C_{F_G}) of changes in nozzle geometric variables depend greatly on the type of nozzle being used. Separate calculation flow paths were constructed to handle each of the following nozzle types:

(1) Axisymmetric Convergent-Divergent
(2) Axisymmetric Plug
(3) Two-Dimensional Convergent-Divergent
(4) Two-Dimensional Plug (Wedge)

The derivative parameters for each nozzle type are:

NOZZLE TYPE	DERIVATIVE PARAMETERS	
AXI C-D	θ_{DIV}	DIVERGENCE HALF-ANGLE
AXI PLUG	θ_P	PLUG HALF-ANGLE
2-D C-D	W_g/H_g θ_{DIV}	ASPECT RATIO DIVERGENCE HALF-ANGLE
2-D WEDGE	W_g/H_g θ_N	ASPECT RATIO RAMP (WEDGE) HALF-ANGLE

The user of the derivative procedure has the options available to calculate the effect on the input C_{F_G} map of any of the derivative parameters shown in the right hand column above. The methods and data used to calculate the effects of variations in each of the derivative parameters are described in the sections which follow.

3.3.1 Effect of Divergence Half-Angle on C_{F_G} for a Round C-D Nozzle

The input map format for round C-D nozzles used by the PIPSI program is illustrated in Figure 34. This map provides C_{F_G} as a function of nozzle pressure ratio, P_{T8}/P_0, for various nozzle expansion ratios, A_9/A_8. To provide a method whereby the effect of θ_{DIV} could be related to area ratio, a typical round C-D nozzle θ_{DIV} variation as a function of A_9/A_8 was adopted for programming into the procedure. With a knowledge of A_9/A_8 and θ_{DIV}, it is possible to determine the angularity loss, using the experimental angularity loss coefficient data shown in Volume I.

3.3.2 Effect of Plug Half-Angle on C_{F_G} for a Round Plug Nozzle

The input map format for an axisymmetric plug nozzle provides nozzle gross thrust coefficient, C_{F_G}, as a function of nozzle pressure ratio P_{T8}/P_0 for various area ratios, A_9/A_8. To obtain the relationship of A_9/A_8 and plug half angle, a two-dimensional table look-up set of data was prepared that represents the geometric relationships between lip angle, α, plug half angle, θ_P, and area ratio, A_9/A_8, for a typical plug nozzle configuration. These data were programmed into the code to provide data necessary to calculate the parameter $(\alpha - \theta_P)$ used in the data correlation that provides the plug nozzle performance loss. This correlation, documented in Volume I, is based on experimental data.

3.3.3 Effect of Aspect Ratio and Divergence Half-Angle on C_{F_G} for a Two-Dimensional Convergent-Divergent Nozzle

The methods used in developing the computer code for the 2-D C-D nozzle internal performance calculations are based primarily on the experimental data gathered during the AFAPL Installed Turbine Engine Survivability Criteria contract. These tests provided data on a variety of 2-D nozzles of various aspect ratios and divergence angles.

The input map format for the 2-D C-D nozzle provides nozzle C_{F_G} as a function of pressure ratio and nozzle jet area. Two jet area schedules are provided, minimum jet area and maximum jet area, corresponding to the experimental configurations tested. An optimum schedule of area ratio is used for each of the jet area settings. The area ratio schedule is truncated at a maximum area ratio of 1.60, corresponding to the maximum area ratio used in the tests. A divergence angle schedule was also obtained from the test configurations. With the geometric relationships provided by the previous A_9/A_8 and θ_{DIV} schedules, the necessary input parameters are available to obtain $C_{F_{G\ PEAK}}$ as a function of A_9/A_8 and θ_{DIV} from a correlation of experimental data. The $C_{F_{G\ PEAK}}$ values for old and new configurations provide the data needed to obtain the ΔC_{F_G} resulting from the geometric change in θ_{DIV}. The data plots are presented in Volume I.

The experimental data were also used to obtain the effect of nozzle aspect ratio. These data, presented in Volume I, provide a correction factor, $C_{F_G}/C_{F_{G\ \text{Æ}=1}}$ as a function of Log Æ for minimum and maximum jet area settings.

3.3.4 Effect of Aspect Ratio and Wedge Half-Angle on C_{F_G} of a 2-D Wedge Nozzle

The format for 2-D wedge nozzle PIPSI input data maps provides C_{F_G} as a function of nozzle pressure ratio, P_{T8}/P_0, for two nozzle area ratio schedules, one for non-afterburning operation and one for maximum afterburning operation. These schedules assume that variable area nozzle geometry is available such that the nozzle area ratio can be scheduled to operate at the optimum value until the geometric limits of nozzle travel are reached.

Experimental data were used to provide the correction factors for 2-D wedge nozzle aspect ratio and wedge angle. The data used in the computer program were prepared as correction factors relative to the baseline values of a wedge angle, θ_p, of 10^o and an aspect ratio, Æ , of 1.0. The resulting correction factors are presented in Volume I.

Flow charts are presented in Section VI which show the calculation procedure used to calculate the new nozzle C_{F_G} maps.

SECTION IV
PROGRAM INPUT AND EXECUTION

The derivative procedure program (DERIVP) is an overlay program written in Extended Fortran IV (FTN) for the ASD CDC NOS/BE computer system. The program is run exclusively in an interactive mode in under 60K octal words of memory.

The inputs to the program consist of maps and derivative parameters on disk files which are attached prior to program execution. User inputs to modify particular derivative parameters are made through interactive input.

The output of the program consists of printed results and a PIPSI input file. The user may select the creation of these output via an interactive input.

4.1 TABLE FORMATS

The values in the tables are stored on disk in a 10F7.0 card format. The meanings of the quantities placed in a card image differ depending on the type of table. There are four table types:

a) one-dimensional
b) two-dimensional (symmetric)
c) two-dimensional (non-symmetric)
d) three-dimensional

In all the input tables the independent variables must always be in increasing order.

4.1.1 One-Dimensional Table Definition

Card 1	Table Definition Card	Format
Cols.		
1-7	Table Name	A7
8-14	Number of X Values	F7.0

Card 2	X Values	
Cols.		
1-7	X_1	F7.0
8-14	X_2	F7.0
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
64-70	X_{10}	F7.0

Card 3	Table Values	
Cols.		
1-7	$f(x_1)$	F7.0
8-14	$f(x_2)$	F7.0
.	.	.
.	.	.
64-70	$f(x_{10})$	F7.0

4.1.2 Two-Dimensional Table Definition (Symmetric)

Card 1	Table definition Card	Format
Cols.		
1-7	Table Title	A7
8-14	Number of X Values	F7.0
15-21	Number of Y Values	F7.0

Card 2	Y Values	
Cols.		
1-7	Y_1	F7.0
8-14	Y_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	Y_{10}	F7.0

Card 3	X Values	
Cols.		
1-7	X_1	F7.0
8-14	X_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	X_{10}	F7.0

Card 4	Table values for Y_1, and all X values	
Cols.		
1-7	$f(x_1,y_1)$	F7.0
8-14	$f(x_2,y_1)$	F7.0
.	.	.
.	.	.
.	.	.
64-70	$f(x_{10},y_1)$	F7.0

Card 5	Table Values for Y_2 and all X Values	
Cols.		
1-7	$f(x_1,y_2)$	F7.0
8-14	$f(x_2,Y_2)$	F7.0
.	.	.
.	.	.
.	.	.
64-70	$f(_{10},y_2)$	F7.0

Etc. for additional Y values

4.1.3 Two-Dimensional Table (Non-Symmetric)

Card 1	Table Definition Card	Format
Cols.		
1-7	Table Name	A7
8-14	Number of Y Values	F7.0

Card 2	Number of X Values for A Particular Y Value	
Cols.		
1-7	NX (Y_1)	F7.0
8-14	NX (Y_2)	F7.0
.	.	.
.	.	.
.	.	.
.	.	.
64-70	NX (Y_{10})	F7.0

Card 3	Y Values	
Cols.		
1-7	Y_1	F7.0
8-14	Y_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	Y_{10}	F7.0

Card 4	X Values for Y_1	
Cols.		
1-7	$X_1(y_1)$	F7.0
8-14	$X_2(y_1)$	F7.0
.	.	.
.	.	.
.	.	.
64-70	$X_{10}(y_1)$	F7.0

Card 5	Table Values for $(X_1\text{-}X_{10},Y_1)$	
Cols.		
1-7	$f(X_1,Y_1)$	F7.0
8-14	$f(X_2,Y_1)$	F7.0
.	.	.
.	.	.
.	.	.
64-70	$f(X_{10},Y_1)$	F7.0

Card 6 X Values for Y_2
(see Card 4)

Card 7 Table Values for $(X_1\text{-}X_{10},Y_2)$
(see Card 5)

4.1.4 Three-Dimensional Table Definition

Card 1	Table Definition Card	Format
Cols.		
1-7	Table Name	A7
8-14	NX = number of X values	F7.0
15-21	NY = number of Y values	F7.0
22-28	NZ = number of Z values	F7.0

Card 2	X Values	
Cols.		
1-7	X_1	F7.0
8-14	X_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	X_{10}	F7.0

Card 3	Y Values	
Cols.		
1-7	Y_1	F7.0
8-14	Y_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	Y_{10}	F7.0

Card 4	Z Values	
Cols.		
1-7	Z_1	F7.0
8-14	Z_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	Z_{10}	F7.0

Card 5	Table Values for Y_1, Z_1, and all X Values	
Cols.		
1-7	$f(X_1,Y_1,Z_1)$	F7.0
8-14	$f(X_2,Y_1,Z_1)$	F7.0
.	.	.
.	.	.
.	.	.
64-70	$f(X_{10},Y_1,Z_1)$	F7.0

Card 6	Table Values for Y_2,Z_1 and all X Values	
Cols.		
1-7	$f(X_1,Y_2,Z_1)$	F7.0
8-14	$f(X_2,Y_2,Z_1)$	F7.0
.	.	.
.	.	.
.	.	.
64-70	$f(X_{10},Y_2,Z_1$	F7.0

Etc. until Y Values have been gone through

Card 5+NX	Table Values for Y_1, Z_2 and all X Values	
Cols.		
1-7	$f(X_1, Y_1, Z_2)$	F7.0
8-14	$f(X_2, Y_1, Z_2)$	F7.0
.	.	.
.	.	.
.	.	.
64-70	$f(X_{10}, Y_1, Z_2)$	F7.0

Etc. until all Y and Z Values have been gone through

4.1.5 Table Examples

Examples of tables in each of the first 3 formats are shown in Figure 4, and an example of the three-dimensional table format is shown in Figure 5.

Table 2E6

.55	.7	.8	1.2	1.6	2.0
1.055	.935	.89	.846	.89	.935

Table Type 1

Tables 7. 8.

0.	.8489	.85	1.0	1.2	1.4	1.7	2.20
0.	.04	.08	.12	.16	.20	.24	
0.	0.	0.	0.	0.	0.	0.	
0.	0.	0.	0.	0.	0.	0.	
0.	.062	.125	.198	.28	.38	.50	
0.	.05	.10	.156	.217	.29	.375	
0.	.036	.075	.117	.162	.22	.29	
0.	.03	.062	.097	.135	.185	.241	
0.	.025	.052	.081	.116	.16	.216	
0.	.02	.045	.074	.11	.153	.21	

Table Type 2

TABLE2A6

7.	6.	7.	7.	8.	9.			
.55	.70	.85	1.20	1.60	2.0			
.7	.8	.9	1.0	1.055	1.075	1.1		
.9915	.991	.985	.969	.95	.933	.875		
.6	.7	.8	.9	.95	.97			
.99	.99	.985	.974	.945	.90			
.5	.6	.7	.8	.85	.875	.905		
.99	.99	.989	.983	.975	.962	.90		
.5	.6	.7	.8	.85	.875	.902		
.98	.979	.977	.973	.967	.955	.90		
.500	.600	.700	.800	.850	.875	.885	.890	
.976	.970	.965	.958	.955	.940	.925	.900	
.5	.6	.7	.8	.9	.93	.935	.943	.95
.958	.953	.949	.944	.935	.925	.92	.900	.85

Table Type 3

Figure 4. Examples of Three Table Types

TABLEAB2.	2.	2.
1.	2.	
1.	2.	
1.	2.	
1.	1.	
1.	1.	
1.	1.	
1.	1.	
2.	2.	
2.	2.	
2.	2.	
2.	2.	

Figure 5 Example of a Three-Dimensional Table

4.2 DISK FILES

The derivative procedure program utilizes three input disk files and two output disk files for program data communication. The user governs the usage of these disk files by responding to prompts when executing the program.

4.2.1 Input Disk Files

Three disk files must be attached prior to program execution in order to run all maps necessary for a PIPSI execution. These files are as follows:

TAPE 51 - Inlet maps and Inlet Derivative Parameters
TAPE 52 - Afterbody Drag Map and Derivative Parameters
TAPE 53 - Nozzle Thrust Coefficient (C_{F_G}) Map and Derivative Parameters

Only the disk files needed to run the desired maps need to be attached before executing the program.

4.2.1.1 Inlet File (TAPE 51)

This disk file consists of four separable sections of input:

1) Inlet Title Card
2) Inlet Derivative Parameters
3) Non-changeable Inlet Parameters
4) Inlet Tables

Figure 6 shows an example of a typical inlet file

4.2.1.1.1 Inlet Title Card

An 80-character title card must be the first card of the inlet file. It is read with an A format and is printed as a heading on the output data.

```
 NVSTO INLET
0.      0.      22.     2.      .015    .46     19.     1.0     20.     1.0
.1      1.0     20.     1.0     .2      1.83    9.9     .12
0.      1.3     3.0     .75     0.
TABLE1 3.
0.      .60     2.0
0.      .60     2.0
TABLE2A7.
10.     10.     10.     10.     10.     10.     10.
.60     .8      1.0     1.4     1.6     1.6     2.0
.5480   .6468   .7479   .7904   .8235   .8460   .8558   .8653   .8695   .8696
.9909   .9667   .9704   .9720   .9647   .9585   .9503   .9340   .9137   .8558
.5352   .5959   .6641   .7106   .7294   .7443   .7530   .7066   .7588   .7559
.9879   .9835   .9754   .9655   .9598   .9531   .9484   .9423   .9352   .8673
.6106   .6781   .6362   .6776   .7154   .7304   .7370   .7401   .7410   .7419
.9840   .9805   .9751   .9687   .9588   .9532   .9485   .9430   .9333   .8664
.5462   .6063   .6627   .7132   .7485   .7673   .7785   .7845   .7878   .7882
.9777   .9761   .9714   .9664   .9611   .9565   .9516   .9442   .9315   .8534
.5979   .6486   .6980   .7498   .7713   .7927   .8154   .8266   .8327   .8334
.9693   .9684   .9666   .9632   .9610   .9578   .9536   .9490   .9428   .8694
.6230   .6978   .7724   .8230   .8680   .8809   .8884   .8945   .8967   .8979
.9640   .9620   .9579   .9535   .9477   .9440   .9409   .9353   .9277   .8649
.6965   .7687   .8227   .8834   .9225   .9465   .9627   .9726   .9771   .9786
.9503   .9488   .9465   .9420   .9377   .9335   .9278   .9211   .9088   .8548
TABLE2B10.
.0003   .2566   .4305   .5680   .6951   .9488   1.1817 1.4746 1.7112 1.9913
.9502   .9591   .9637   .9664   .9668   .9658   .9637   .9583   .9510   .9360
TABLE2C10.
.4477   .5319   .6523   .7361   .7909   .8964   1.0180 1.2124 1.5834 1.9822
1.0004  .8835   .7763   .7340   .7173   .6991   .6961   .7208   .8121   .9415
TABLE2D10.
1.3795 1.3982 1.4354 1.4775 1.5510 1.6344 1.7074 1.7904 1.8735 1.9876
.4003   .5479   .5682   .5712   .5895   .6064   .6209   .6383   .6497   .6689
TABLE2L10.
.5338   .6779   .8576   .9311   .9959   1.0982 1.2955 1.5267 1.6995 1.9885
.9990   .8695   .7766   .7541   .7499   .7553   .7866   .8416   .8872   .9480
TABLE3 10.,
2.      2.      10.     10.     10.     10.     10.     10.     10.     10.
0.      .59     .60     .8      .95     1.06    1.4     1.6     1.8     2.0
.30     1.0
0.0     0.0
.30     1.0
0.0     0.0
.35     .382    .417    .449    .479    .503    .548    .568    .586    1.0
.059    .046    .034    .025    .017    .011    .004    .001    .00     .00
.351    .383    .416    .45     .49     .528    .606    .639    .671    1.0
.118    .1      .083    .066    .05     .036    .013    .005    .00     .00
.344    .384    .422    .462    .5      .541    .591    .681    .746    1.0
.179    .145    .119    .096    .077    .059    .038    .009    .00     .00
.347    .394    .442    .488    .531    .579    .621    .703    .746    1.0
.224    .183    .149    .12     .093    .067    .047    .013    .00     .00
.325    .39     .443    .51     .564    .617    .716    .754    .787    1.0
.326    .278    .241    .195    .156    .12     .051    .022    .001    0.0
.378    .451    .517    .573    .625    .674    .768    .805    .84     1.0
.615    .518    .431    .357    .287    .22     .094    .048    0.0     0.0
.443    .504    .563    .614    .673    .728    .786    .876    .91     1.0
.721    .624    .535    .456    .364    .279    .190    .052    .001    0.0
.509    .564    .646    .702    .753    .855    .905    .951    .99     1.0
.799    .672    .571    .479    .392    .223    .141    .064    0.0     0.0
```

Figure 6. Inlet File Example

```
TABLE3A2.
0.0      .6       .7       .8       1.0      1.2      1.6      2.0
0.0      0.0      .04      .068     .09      .074     .034     .002
TABLE3B2.
0.0      .40      1.0      1.2      1.4      1.6      1.8      2.0
.743     .743     .743     .752     .785     .639     .907     .99
TABLE4 10.        3.
0.       .85      2.
.0000    .0037    .0097    .0143    .0199    .0296    .0403    .0642    .0876    .1073
.0600    .0099    .0164    .0219    .0249    .0273    .0281    .0265    .0236    .0198
.0000    .0099    .0184    .0219    .0249    .0273    .0281    .0265    .0236    .0198
.0000    .0099    .0184    .0219    .0249    .0273    .0281    .0265    .0236    .0398
TABLE5 6.         4.
.85      1.2      1.7      2.0
0.0      .04      .08      .12      .16      .20      .24
0.0      .05      .155     .30      .47      .66      .87
0.0      .04      .127     .257     .405     .57      .75
0.0      .024     .093     .202     .331     .478     .635
0.0      .02      .06      .105     .175     .258     .348
TABLE6A6.
2.       2.       10.      10.      10.      10.
0.0      .79      .60      1.2      1.6      2.0
0.0      1.0
0.0      0.0
0.0      1.0
0.0      0.0
.4991    .5344    .5570    .5808    .6047    .6311    .6562    .6776    .6952    .7153
.0216    .0184    .0160    .0136    .0110    .0086    .0059    .0040    .0022    .0003
.5003    .5485    .5877    .6269    .6673    .7039    .7277    .7473    .7616    1.0006
.0320    .0305    .0286    .0271    .0252    .0227    .0198    .0134    .0052    .0051
.5917    .5753    .6551    .7373    .7852    .8002    .8126    .8320    .8470    1.0009
.0435    .0421    .0397    .0360    .0327    .0306    .0280    .0201    .0073    .0072
.4980    .6476    .7606    .8716    .9145    .9371    .9545    .9711    .9885    1.0012
.0663    .0631    .0587    .0547    .0519    .0490    .0457    .0352    .0102    .0101
TABLE6B10.
.8162    .9882    1.1286   1.2431   1.3575   1.4875   1.6072   1.7322   1.8571   1.9976
0.0      .0075    .0135    .0182    .0220    .0283    .0332    .0385    .0441    .0501
TABLE7 8.
2.       2.       10.      10.      10.      10.      10.      10.
0.0      1.09     1.1      1.2      1.4      1.6      1.8      2.0
.3981    1.0
.00      0.0
.3981    1.0
.00      0.0
.3981    .4270    .4546    .4860    .5249    .5689    .6115    .6505    .6793    .7032
.3025    .2743    .2460    .2152    .1766    .1356    .0918    .0533    .0250    .0006
.3983    .4321    .4660    .5025    .5414    .5778    .6205    .6594    .6895    .7159
.3178    .2818    .2484    .2125    .1739    .1379    .0968    .0583    .0287    .0006
.3981    .4363    .4753    .5152    .5631    .5963    .6372    .6761    .7163    .7603
.3559    .3174    .2801    .2364    .1940    .1606    .1221    .0835    .0424    0.0
.3967    .4544    .5021    .5448    .5951    .6352    .6767    .7281    .7658    .8085
.4081    .3502    .3027    .2603    .2140    .1729    .1318    .0804    .0419    .0008
.3973    .4639    .5204    .5731    .6283    .6836    .7338    .7853    .8241    .8693
.4676    .4335    .3463    .2943    .2391    .1864    .1350    .0849    .0438    .0001
.3968    .4709    .5399    .6052    .6642    .7219    .7772    .8374    .8901    .9391
.5390    .4657    .3976    .3334    .2743    .2152    .1612    .0996    .0482    0.0
```

Figure 6. Inlet File Example (concluded)

4.2.1.1.2 Inlet Derivative Parameters

The inlet derivative parameters provide the basic information describing the configuration in terms of its important parameters. These data are used by the derivative program as a starting point from which a new configuration performance is derived.

Card 1 Cols.	Parameter Definition	Format
1-7	Aspect Ratio (2D)	F7.0
8-14	Sideplate Cutback (2D)	F7.0
15-21	First Ramp (cone) angle (deg)	F7.0
22-28	Mach Number	F7.0
29-35	Cowl Lip Bluntness	F7.0
36-42	Takeoff Door Area	F7.0
43-49	External Cowl Angle (deg)	F7.0
50-56	Exit Nozzle Type for Bleed	F7.0
57-63	Exit Nozzle Angle for Bleed (deg)	F7.0
64-70	Exit Flap Aspect Ratio for Bleed	F7.0

Card 2 Cols.		
1-7	Exit Flap Area for Bleed	F7.0
8-14	Exit Nozzle Type for Bypass	F7.0
15-21	Exit Nozzle Angle for Bypass (deg)	F7.0
22-28	Exit Flap Aspect Ratio for Bypass	F7.0
29-35	Exit Flap Area for Bypass	F7.0
36-42	Subsonic Diffuser Area Ratio	F7.0
43-49	Subsonic Diffuser Total Wall Angle (deg)	F7.0
50-56	Subsonic Diffuser Loss Coefficient	F7.0
57-63	Throat to Capture Area Ratio(PITOT)	F7.0

4.2.1.1.3 Non-changeable Inlet Parameters

The non-changeable parameters provide information about the basic design ground rules of the mapped configuration.

Card 1 Cols.	Parameter Definition	Format
1-7	Geometry Type 0. = axisymmetric inlet 1. = 2-D inlet 2. - PITOT inlet	F7.0
8-14	Nominal Normal Shock Mach Number	F7.0
15-21	Starting Mach Number	F7.0
22-28	Nominal Throat Mach Number	F7.0

4.2.1.1.4 Inlet Tables

The inlet map file consists of 14 tables. The tables are input in sequential order and are listed below. More detail about the use of these tables can be found in the PIPSI Users Manual, Volume II.

Table 1

A Type 1 table of Local Mach Number versus Freestream Mach Number

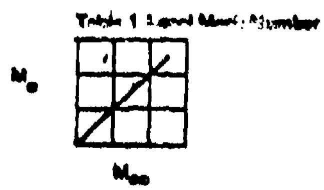


Table 2A

A Type 3 table of Recovery versus Mass Flow and Local Mach Number

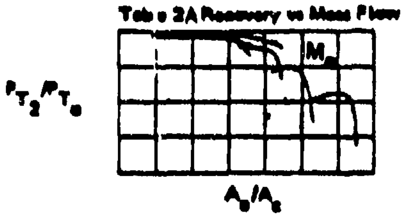


Table 2B

A Type 1 table of Matched Inlet Recovery versus Local Mach Number

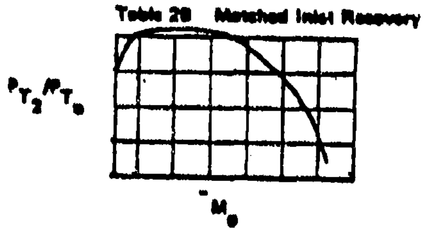


Table 2C

A Type 1 table of Matched Mass Flow versus Local Mach Number

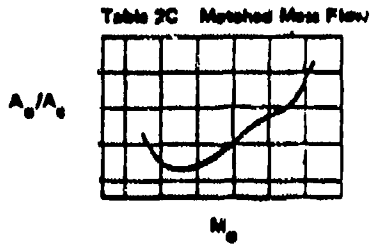


Table 2D

A Type 1 table of Buzz Limit versus Local Mach Number

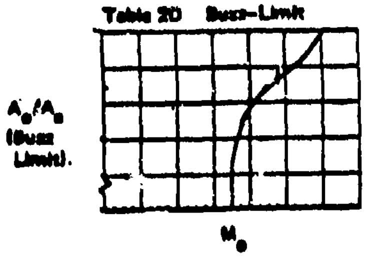


Table 2E

A Type 1 table of Distortion Limit versus Local Mach Number

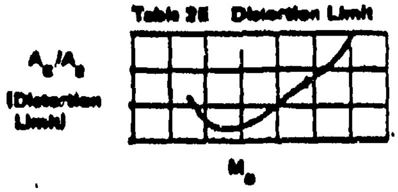


Table 3

A Type 3 table of Spillage Drag versus Inlet Supply ratio and Local Mach number

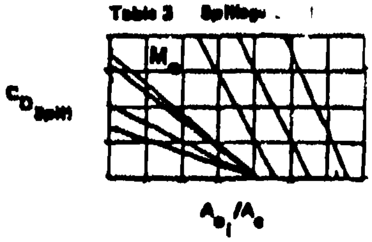


Table 3A

A Type 1 table of Reference Spillage Drag versus Local Mach Number

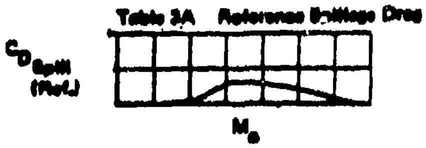


Table 3B

A Type 1 table of Reference Mass Flow versus Local Mach Number

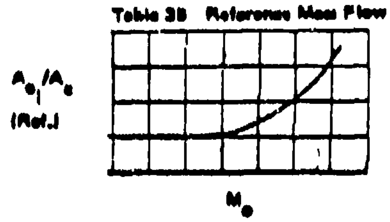


Table 4

A Type 2 table of Boundary Layer Bleed Drag versus Bleed Supply ratio and Local Mach Number

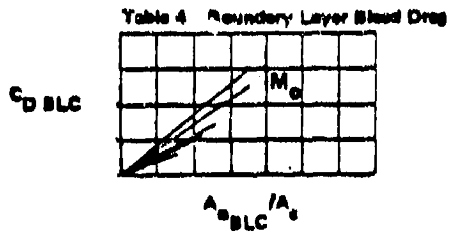


Table 5

A Type 2 table of Bypass Drag versus Bypass Supply ratio and Local Mach Number

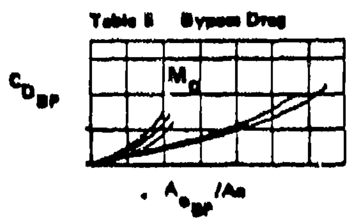


Table 6A

A Type 3 table of Bleed Supply ratio versus Ao/Ac and Local Mach Number

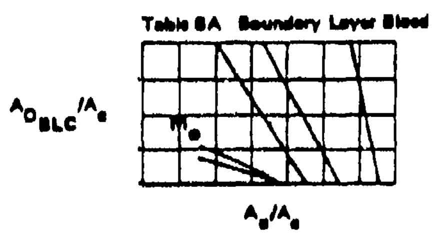


Table 6B

A Type 1 table of Matched Boundary Layer Bleed ratio versus Local Mach Number

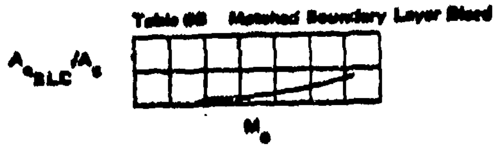


Table 7

A Type 3 table of Bypass ratio versus Engine Supply ratio and Local Mach Number

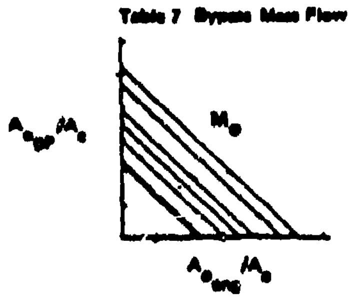
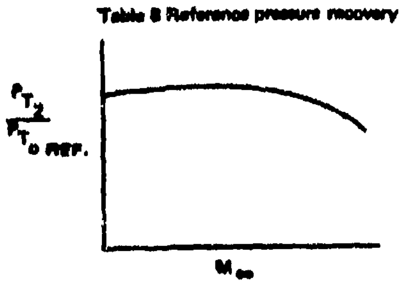


Table 8

This is an optional type 1 table of reference recovery factor versus free stream Mach number.



The derivative procedure program does not perform any operations on this table. It just transfers it along to the TAPE1 output file for PIPSI usage.

4.2.1.2 Afterbody file (TAPE 52)

This disk file consists of five separate sections

(1) Afterbody Title Card
(2) Afterbody Derivative Parameters
(3) Afterbody Location versus Area Curves
(4) Non-changeable Afterbody Parameters
(5) Afterbody Drag Table

Figure 7 is an example of a typical afterbody file.

4.2.1.2.1 Afterbody Title Card

An 80-character title card must be the first card of the afterbody file. It is read with an A format and is printed as a heading on the output data.

4.2.1.2.2 Afterbody Derivative Parameters

The afterbody derivative parameters provide the basic information describing the configuration in terms of its important parameters. These data are used by the derivative program as a starting point from which a new configuration performance is derived.

Card 1 Cols.	Parameter Definition	Format
1-7	Nozzle Static Pressure Ratio	F7.0
8-14	Tail Fin Configurations (0., 1. or 2)	F7.0
15-21	Tail Fin Angle (deg)	F7.0
22-28	Tail Fin Fore-and-Aft Location Ratio	F7.0
29-35	Base Area Ratio	F7.0

4.2.1.2.3 Afterbody Location Versus Area Curves

The area curves are used to calculate the IMS_T parameter which is the basic afterbody drag correlation parameter. For each A10/A9 curve in the $C_{D_{AB}}$ table, there corresponds a nozzle aftbody area versus location distribution.

```
CD2R INPUT MAP
1.0     2.0     0.      .1736   0.
5.
7.      7.      7.      7.      7.
637.    700.    760.    800.    820.    830.    876.
44.5    41.5    36.     31.     25.     20.5    20.5
637.    700.    760.    800.    820.    830.    876.
44.5    41.5    36.     31.     25.     20.5    17.84
637.    700.    760.    800.    820.    830.    876.
44.5    41.5    36.     31.     25.     20.5    13.39
637.    700.    760.    800.    820.    830.    876.
44.5    41.5    36.     31.     25.     20.5    8.92
637.    700.    760.    800.    820.    830.    876.
44.5    41.5    36.     31.     25.     20.5    6.
0.      2.      0.
TABLEAB8.       5.
2.18    2.50    3.33    5.      7.43
.4      .9      1.13    1.2     1.4     1.6     2.0     2.3
.037    .037    .096    .084    .065    .055    .045    .042
.048    .048    .107    .095    .072    .063    .053    .048
.064    .064    .138    .122    .094    .081    .066    .06
.075    .075    .18     .156    .12     .103    .085    .077
.083    .083    .226    .20     .148    .122    .100    .090
```

Figure 7. Afterbody File Example

Card 1		Format
Cols.		
1-7	Number of Curves	F7.0

Card 2	Number of Points/Curve	Format
Cols.		
1-7	No. Points for Curve 1	F7.0
8-14	No. Points for Curve 2	F7.0
.	.	.
.	.	.
.	.	.
64-70	No. Points for Curve 10	F7.0

Card 3	Curve 1 Location Values (in)	Format
Cols.		
1-7	X_1	F7.0
8-14	X_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	X_{10}	F7.0

Card 4	Curve 2 Area Values (Sq. Ft.)	
Cols.		
1-7	A_1	F7.0
8-14	A_2	F7.0
.	.	.
.	.	.
.	.	.
64-70	A_{10}	F7.0

Etc. for the rest of the Area Ratios in $C_{D_{AB}}$ Table

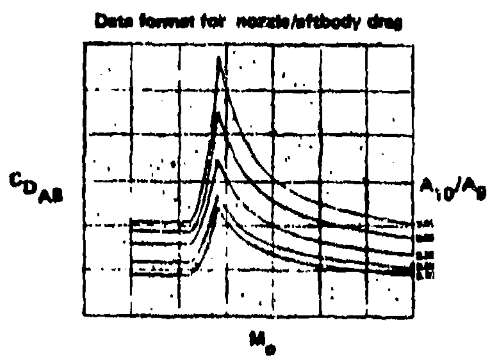
4.2.1.2.4 Non-changeable Afterbody Parameters

The non-changeable afterbody parameters provide additional basic information describing the configuration and its important parameters.

Card 1 Cols.	Other Parameters	Format
1-7	Geometry Type	F7.0
	0. axisymmetric	
	1. 2-D	
8-14	Afterbody Type	F7.0
	1. = CD Axisymmetric Single Nozzle	
	2. = CD Axisymmetric Dual Nozzle	
	3. = CD 2-D Single Nozzle	
	4. = CD 2-D Dual Nozzle	
	5. = Plug Axisymmetric Single Nozzle	
	6. = Plug Axisymmetric Dual Nozzle	
	7. = Wedge 2-D Single Nozzle	
	8. = Wedge 2-D Dual Nozzle	

4.2.1.2.5 Afterbody Drag Table

The afterbody drag table is a Type 2 table of Afterbody Drag versus A10/A9 and local Mach Number



The same table format is used for both round and two-dimensional nozzles; however, the afterbody drag coefficient in the input table for the two-dimensional nozzle is defined differently from that for the round nozzle input. These coefficients are defined as follows:

For Round Nozzle:

$$C_{D\,AB} = \frac{D_{AB}}{q_o A_{10}}$$

For Two-Dimensional Nozzle:

$$C_{D\,AB} = \frac{D_{AB}}{q_o (A_{10} - A_9)}$$

The definitions for the two nozzle/aftbody drag coefficients are different because the experimental data for the two-dimensional nozzle as obtained were nearly all based on the projected aftbody area, $(A_{10}-A_9)$, rather than the cross-sectional reference area, A_{10}, as was the case for the round nozzle. Therefore, for two-dimensional nozzles, the input drag coefficient was defined as shown above to make the most direct use of the available experimental data.

The derivative procedure program processes the calculations of new inlet, afterbody drag, and nozzle internal performance using separate files of input data and separate procedures in the computer code. It is possible, therefore, to run any combination of inlet, nozzle/aftbody, and nozzle configurations during execution of the program. The results of the program calculations are stored on output TAPE1. The user must then split off the results into files that are used as input to PIPSI.

4.2.1.3 Nozzle Thrust Coefficient File (TAPE 53)

This disk file consists of four separate sections

(1) Nozzle Title Card
(2) Derivative Parameters
(3) Non-changeable Nozzle Parameters
(4) Nozzle Thrust Coefficient Table

Figure 8 is an example of a typical nozzle thrust coefficient file.

```
CV1 INPUT MAP
0.      0.      0.      11.45
0.      1.      0.
TABLECV10.      7.
1.      1.1     1.2     1.3     1.4     1.5     1.6
1.5     2.0     3.0     4.0     5.0     6.0     8.0     10.     14.     18.
.992    .992    .986    .976    .966    .955    .938    .924    .903    .886
.932    .965    .984    .986    .982    .975    .960    .947    .925    .908
.888    .935    .977    .986    .988    .983    .970    .958    .938    .92
.862    .905    .965    .982    .986    .982    .972    .964    .947    .932
.840    .85     .942    .970    .983    .986    .976    .968    .954    .942
.822    .876    .932    .962    .977    .982    .978    .970    .959    .946
.8      .867    .922    .952    .97     .979    .978    .972    .961    .952
```

Figure 8. Nozzle Thrust Coefficient File Example

4.2.1.3.1 Nozzle Title Card

An 80 character title card must be the first card of the nozzle file. It is read with an A format and is printed as a heading on the output data.

4.2.1.3.2 Derivative Parameters

The nozzle/aftbody derivative parameters provide the basic information describing the configuration in terms of its important parameters. These data are used by the derivative program as a starting point from which a new configuration performance is derived.

Card 1 Cols.	Parameter Definition	Format
1-7	Plug Half Angle (deg)	F7.0
8-14	Wedge Half Angle (deg)	F7.0
15-21	Aspect Ratio	F7.0
22-28	Divergence Half Angle (deg)	F7.0

4.2.1.3.3 Non-changeable Nozzle Parameters

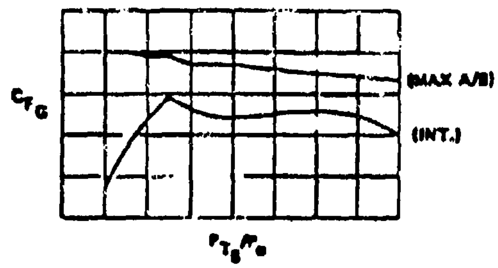
The non-changeable parameters provide information describing the configuration in terms of important basic parameters that were used to derive the performance maps. They describe the configuration but are not used in the interactive sessions.

Card 1 Cols.	Parameter Definition	Format
1-7	Nozzle Type 1 = Round Convergent-Divergent 2 = 2-D Wedge 3 = Round Plug 4 = 2-D Convergent-Divergent	F7.0

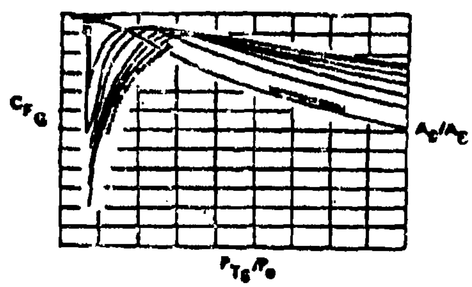
4.2.1.3.4 Nozzle Thrust Coefficient Table

The format of the table varies depending on whether the user has selected a round or 2-dimensional nozzle.

For a 2-dimensional nozzle the table is a Type 2 table of nozzle thrust coefficient versus P_{T_8}/P_0 and PS.



For a round nozzle the table is a Type 2 table of nozzle thrust coefficient versus A_9/A_8 and P_{T_8}/P_0.



4.2.2 Output Disk Files

The user selects the output options through responses to prompts while executing the derivative procedure program interactively. There are three disk files used for output:

TAPE 6 for printed output
TAPE 1 for new PIPSI file

4.2.2.1 TAPE 6 Output

The output on TAPE 6 is always obtained when the derivative procedure is executed. It contains a listing of the old maps and derivative parameters and a listing of the resulting new maps and derivative parameters. If a hard copy of the results is needed, the file can be disposed for off-line printing. An example of this output is given in Figure 9.

4.2.2.2 TAPE 1 Output

The TAPE1 (new PIPSI file) is formatted exactly like the input disk file (either TAPE 51, TAPE 52, or TAPE 53, whichever was used as input; see Figures 6, 7, and 8). This file is generated only if the user wishes to run the PIPSI program and perform an execution. If the user uses this file to run DERIVP, a message will appear at the terminal, indicating to the user that the input was from a previous derivative procedure execution and the program will abort.

4.3 Interactive Input

In order to execute the derivative procedure program, the user must provide interactive inputs via a terminal. Figure 10 shows an example of typical terminal session.

The terminal prompts and a typical set of user responses are enumerated as follows:

4.3.1 Map Type Code

The user may input either

1) for inlet map file (TAPE 51)
2) for afterbody drag file (TAPE 52)
3) for nozzle thrust coefficient file (TAPE 53)

The option selected means that the user must have previously attached that particular file.

```
                                   OLD  INLET     MAPS

                   ATS2 INLET MAP

                                   LOCAL MACH NUMBER

TABLE1    NUMBER OF POINTS =       3.
  0.000    .200  2.000
  0.000    .200  2.000

                                   RECOVERY VS MASS FLOW

TABLE2A  NUMBER OF Y POINTS =       6.
NUMBER OF X POINTS =      7.      6.      7.      7.      8.      9.
   .950    .700    .850  1.200   1.600   2.000
   .700    .800    .900  1.000   1.055   1.075   1.100
   .992    .991    .985   .969    .950    .933    .875
   .600    .700    .800   .900    .950    .970
   .990    .990    .985   .974    .945    .900
   .500    .600    .700   .800    .850    .875    .905
   .990    .993    .989   .983    .975    .962    .900
   .500    .600    .700   .800    .850    .875    .902
   .980    .979    .977   .973    .967    .955    .900
   .500    .600    .700   .800    .850    .875    .885    .890
   .978    .970    .965   .958    .955    .940    .925    .900
   .500    .600    .700   .800    .900    .930    .935    .943    .950
   .958    .953    .949   .944    .935    .925    .920    .900    .850

                                   MATCHED INLET RECOVERY

TABLE2B   NUMBER OF POINTS =       9.
  0.000    .200    .400    .800    .900  1.000   1.200   1.600   2.000
   .900    .950    .965    .972    .975   .975    .967    .948    .925

                                   MATCHED MASS FLOW

TABLE2C   NUMBER OF POINTS =       7.
   .400    .600    .800  1.000   1.200   1.600   2.000
  1.310    .968    .863   .830    .840    .872    .915

                                   BUZZ LIMIT

TABLE2D   NUMBER OF POINTS =       6.
  0.000  1.399   1.400   1.600   1.800   2.000
  0.000  0.000    .400    .500    .560    .600
```

Figure 9. Example of TAPE6 Output

```
                                                  DISTORTION LIMIT

TABLE2E  NUMBER OF POINTS =      6.
    .550    .700    .800  1.200  1.600  2.000
   1.055    .935    .890   .846   .890   .935

                                                  SPILLAGE DRAG

TABLE3   NUMBER OF Y POINTS =         9.
NUMBER OF X POINTS =      2.      2.      7.      9.      9.      9.      7.      7.      7.
   0.000    .549    .550    .700    .850   1.200   1.400   1.600   2.000
   0.000   1.000
   0.000   0.000
   0.000   1.000
   0.000   0.000
    .300    .400    .500    .600    .700    .715   1.000
    .185    .110    .052    .015    .002   0.000   0.000
    .300    .400    .500    .600    .700    .800    .900    .950   1.000
    .310    .207    .123    .062    .032    .015    .005   0.000   0.000
    .300    .400    .500    .600    .700    .800    .900    .963   1.000
    .410    .280    .175    .098    .050    .026    .010   0.000   0.000
    .300    .400    .500    .600    .700    .800    .900    .958   1.000
    .500    .360    .240    .150    .086    .038    .014   0.000   0.000
    .300    .500    .700    .800    .887    .909   1.000
    .750    .437    .210    .110    .022   0.000   0.000
    .500    .600    .700    .800    .915    .928   1.000
    .715    .550    .370    .210    .021   0.000   0.000
    .500    .700    .800    .900    .957    .962   1.000
    .840    .480    .298    .118    .010   0.000   0.000

                                                  REFERENCE SPILLAGE DRAG

TABLE3A  NUMBER OF POINTS =      3.
   0.000   1.000   2.000
   0.000   0.000   0.000

                                                  REFERENCE MASS FLOW

TABLE3B  NUMBER OF POINTS =      3.
   0.000   1.000   2.000
   1.000   1.000   1.000

                                                  BOUNDARY LAYER BLEED DRAG

TABLE4   NUMBER OF X-POINTS=         5.  NUMBER OF Y-POINTS=        6.
   0.000    .849    .850   1.200   1.700   2.000
   0.000    .010    .020    .040    .060
   0.000   0.000   0.000   0.000   0.000
   0.000   0.000   0.000   0.000   0.000
   0.000    .007    .014    .028    .042
   0.000    .010    .021    .042    .062
   0.000    .011    .022    .044    .066
   0.000    .013    .026    .052    .078
```

Figure 9. Example of TAPE6 Output (continued)

```
                                 BYPASS DRAG

TABLE5   NUMBER OF X-POINTS=       7.  NUMBER OF Y-POINTS=      8.
  0.000   .849   .850  1.000  1.200  1.400  1.700  2.200
  0.000   .040   .080   .120   .160   .200   .240
  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  0.000   .062   .125   .198   .280   .380   .500
  0.000   .050   .100   .156   .217   .290   .375
  0.000   .036   .075   .117   .162   .220   .290
  0.000   .030   .062   .097   .135   .185   .241
  0.000   .025   .052   .081   .116   .160   .216
  0.000   .020   .045   .074   .110   .153   .210

                                 BOUNDARY LAYER BLEED DRAG

TABLE5A  NUMBER OF Y POINTS =        8.
NUMBER OF X POINTS =       2.     2.     5.     5.     5.     6.     6.     6.
  0.000   .900  1.000  1.200  1.400  1.600  1.800  2.000
  0.000  1.000
  0.000  0.000
  0.000  1.000
  0.000  0.000
   .800   .700   .831   .900  1.000
   .008   .007   .005   .003  0.000
   .600   .700   .840   .900  1.000
   .014   .013   .010   .008  0.000
   .600   .700   .859   .900  1.000
   .022   .020   .015   .012  0.000
   .600   .700   .800   .881   .930  1.000
   .030   .029   .026   .020   .014  0.000
   .600   .700   .800   .906   .930  1.000
   .044   .042   .037   .025   .021  0.000
   .600   .700   .800   .900   .930  1.000
   .060   .056   .050   .037   .030  0.000

                                 MATCHED BOUNDARY LAYER BLEED

TABLE6B  NUMBER OF POINTS =        5.
  0.000   .900  1.200  1.600  2.000
  0.000  0.000   .010   .020   .030
```

Figure 9. Example of TAPE6 Output (continued)

BYPASS MASS FLOW

```
TABLE7    NUMBER OF Y POINTS =       6.
NUMBER OF X POINTS =        2.       2.       4.       4.       4.       4.
  0.000   1.399   1.400   1.600   1.800   2.000
  0.000   1.000
  0.000   0.000
  0.000   1.000
  0.000   0.000
   .400    .854    .859   1.000
   .461    .005   0.000   0.000

   .400    .872    .882   1.000
   .483    .010   0.000   0.000
   .400    .892    .906   1.000
   .506    .014   0.000   0.000
   .400    .915    .930   1.000
   .532    .015   0.000   0.000
```

INLET MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	OLD VALUE
1	ASPECT RATIO	1.0000
2	SIDEPLATE CUTBACK	.2000
3	FIRST RAMP ANGLE(DEG)	7.3000
4	DESIGN MACH NUMBER	2.0000
5	COWL LIP BLUNTNESS	.0200
6	TAKE OFF DOOR AREA	.2000
7	EXTERNAL COWL ANGLE(DEG)	17.5000
8	EXIT NOZZLE TYPE FOR BLEED	1.0000
9	EXIT NOZZLE ANGLE FOR BLEED(DEG)	15.0000
10	EXIT FLAP ASPECT RATIO FOR BLEED	2.0000
11	EXIT FLAP AREA FOR BLEED	.1000
12	EXIT NOZZLE TYPE FOR BYPASS	1.0000
13	EXIT NOZZLE ANGLE FOR BYPASS(DEG)	15.0000
14	EXIT FLAP ASPECT RATIO FOR BYPASS	2.0000
15	EXIT FLAP AREA FOR BYPASS	.2000
16	SUBSONIC DIFFUSER AREA RATIO	1.5000
17	SUBSONIC DIFFUSER TOTAL WALL ANGLE(DEG)	10.0000
18	SUBSONIC DIFFUSER LOSS COEFFICIENT	.1000

Figure 9. Example of TAPE6 Output (continued)

```
                                             NEW  INLET     MAPS

                 ATS2 INLET MAP


                                             LOCAL MACH NUMBER

TABLE1   NUMBER OF POINTS =       3.
  0.000    .200   2.100
  0.000    .200   2.100

                                             RECOVERY VS MASS FLOW

TABLE2A  NUMBER OF Y POINTS =          6.
NUMBER OF X POINTS =        7.       6.       7.       7.       8.       9.
   .550    .700    .850   1.220   1.660   2.100
   .667    .762    .857    .953   1.009   1.024   1.048
   .992    .991    .985    .969    .950    .933    .875
   .572    .667    .762    .857    .905    .924
   .990    .990    .989    .974    .955    .900
   .476    .571    .667    .762    .810    .833    .862
   .990    .990    .989    .983    .975    .962    .900
   .481    .578    .674    .771    .819    .843    .869
   .979    .978    .976    .972    .966    .954    .899
   .490    .589    .687    .786    .835    .859    .869    .874
   .972    .968    .961    .954    .951    .938    .921    .896
   .499    .599    .700    .800    .900    .930    .935    .943    .950
   .950    .945    .941    .936    .927    .917    .912    .892    .842

                                             MATCHED INLET RECOVERY

TABLE2B  NUMBER OF POINTS =       9.
  0.000    .200    .400    .600    .800   1.000   1.220   1.660   2.100
   .900    .950    .965    .972    .975    .975    .966    .944    .917

                                             MATCHED MASS FLOW

TABLE2C  NUMBER OF POINTS =       7.
   .400    .600    .800   1.000   1.220   1.660   2.100
  1.248    .922    .822    .790    .809    .857    .919

                                             BUZZ LIMIT

TABLE2D  NUMBER OF POINTS =       6.
  0.000   1.439   1.440   1.660   1.880   2.100
  0.000   0.000    .869    .869    .874    .874
```

Figure 9. Example of TAPE6 Output (continued)

```
                                        DISTORTION LIMIT

 TABLE2E   NUMBER OF POINTS =       6.
    .550     .700     .800   1.220   1.660   2.100
    .337     .572     .476    .481    .490    .499


                                        SPILLAGE DRAG

 TABLE3    NUMBER OF Y POINTS =          9.
 NUMBER OF X POINTS =        2.       2.       7.       9.       9.       9.       7.       7.       7.
   0.000     .549     .550     .700     .850   1.220   1.440   1.660   2.100
   0.000    1.000
   0.000    0.000
   0.000    1.000
   0.000    0.000
    .286     .381     .476     .572     .667     .681   1.000
    .181     .107     .050     .014     .002   0.000   0.000
    .286     .381     .476     .572     .667     .762     .857     .905   1.000
    .304     .202     .119     .059     .030     .012     .005   0.000   0.000
    .286     .381     .476     .572     .667     .762     .857     .917   1.000
    .402     .273     .170     .094     .047     .021     .043   0.000   0.000
    .289     .386     .482     .578     .675     .771     .868     .924   1.000
    .227     .146     .084     .043     .019     .006     .001   0.000   0.000
    .292     .487     .681     .779     .864     .883   1.000
    .756     .447     .220     .118     .025   0.000   0.000
    .492     .590     .688     .786     .900     .912   1.000
    .733     .568     .388     .223     .027   0.000   0.000
    .500     .701     .801     .901     .958     .963   1.000
    .862     .499     .312     .125     .010   0.000   0.000


                                        REFERENCE SPILLAGE DRAG

 TABLE3A   NUMBER OF POINTS =       3.
   0.000    1.000    2.100
   0.000    0.000    0.000


                                        REFERENCE MASS FLOW

 TABLE3B   NUMBER OF POINTS =       3.
   0.000    1.000    2.100
   1.000    1.000    1.000


                                        BOUNDARY LAYER BLEED DRAG

 TABLE4    NUMBER OF X-POINTS=          5.  NUMBER OF Y-POINTS=          6.
   0.000     .849     .850   1.220   1.770   2.100
   0.000     .010     .020     .041     .061
   0.000    0.000    0.000    0.000    0.000
   0.000    0.000    0.000    0.000    0.000
   0.000     .007     .014     .028     .042
   0.000     .010     .021     .042     .062
   0.000     .011     .022     .044     .066
   0.000     .012     .025     .050     .075
```

Figure 9. Example of TAPE6 Output (continued)

```
                                                  BYPASS DRAG

TABLE5     NUMBER OF X-POINTS=       7.  NUMBER OF Y-POINTS=       8.
  0.000     .849    .850   1.000   1.220   1.440   1.770   2.320
  0.000     .041    .081    .122    .162    .203    .243
  0.000    0.000   0.000   0.000   0.000   0.000   0.000
  0.000    0.000   0.000   0.000   0.000   0.000   0.000
  0.000     .082    .125    .198    .280    .380    .500
  0.000     .050    .100    .156    .217    .290    .375
  0.000     .036    .075    .117    .162    .220    .290
  0.000     .030    .062    .097    .139    .184    .240
  0.000     .025    .052    .082    .117    .160    .226
  0.000     .021    .046    .076    .113    .157    .215

                                                  BOUNDARY LAYER BLEED DRAG

TABLE6A    NUMBER OF Y POINTS =         8.
NUMBER OF X POINTS =        2.      2.      5.      5.      5.      6.      6.      6.
  0.000     .800   1.000   1.220   1.440   1.660   1.880   2.100
  -.000     .953
  0.000    0.000
  -.000     .953
  0.000    0.000
   .574     .670    .795    .861    .957
   .008     .007    .005    .003   0.000
   .578     .674    .809    .867    .964
   .014     .013    .010    .008   0.000
   .583     .681    .836    .876    .973
   .022     .020    .015    .012   0.000
   .589     .687    .788    .885    .914    .983
   .031     .030    .027    .020    .014   0.000
   .594     .693    .793    .898    .922    .992
   .049     .045    .038    .028    .021   0.000
   .599     .700    .800    .900    .930   1.001
   .061     .057    .051    .038    .031   0.000

                                                  MATCHED BOUNDARY LAYER BLEED

TABLE6B    NUMBER OF POINTS =        5.
  0.000     .800   1.220   1.880   2.100
  0.000    0.000    .010    .020    .031

                                                  BYPASS MASS FLOW

TABLE7     NUMBER OF Y POINTS =        6.
NUMBER OF X POINTS =        2.      2.      4.      4.      4.      4.
  0.000    1.439   1.440   1.660   1.880   2.100
  0.000    1.000
  0.000    0.000
  0.000    1.000
  0.000    0.000
   .384     .831    .836   1.000
   .444     .005   0.000   0.000
   .398     .857    .857   1.000
   .475     .010   0.000   0.000
   .398     .886    .900   1.000
   .503     .014   0.000   0.000
   .402     .919    .934   1.000
   .534     .015   0.000   0.000
```

Figure 9. Example of TAPE6 Output (continued)

INLET MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	NEW VALUE
1	ASPECT RATIO	1.0000
2	SIDEPLATE CUTBACK	.2000
3	FIRST RAMP ANGLE(DEG)	7.1000
4	DESIGN MACH NUMBER	2.1000
5	COWL LIP BLUNTNESS	.0200
6	TAKE OFF DOOR AREA	.2000
7	EXTERNAL COWL ANGLE(DEG)	17.5000
8	EXIT NOZZLE TYPE FOR BLEED	1.0000
9	EXIT NOZZLE ANGLE FOR BLEED(DEG)	15.0000
10	EXIT FLAP ASPECT RATIO FOR BLEED	2.0000
11	EXIT FLAP AREA FOR BLEED	.1000
12	EXIT NOZZLE TYPE FOR BYPASS	1.0000
13	EXIT NOZZLE ANGLE FOR BYPASS(DEG)	15.0000
14	EXIT FLAP ASPECT RATIO FOR BYPASS	2.0000
15	EXIT FLAP AREA FOR BYPASS	.2000
16	SUBSONIC DIFFUSER AREA RATIO	1.7000
17	SUBSONIC DIFFUSER TOTAL WALL ANGLE(DEG)	11.0000
18	SUBSONIC DIFFUSER LOSS COEFFICIENT	.1417

Figure 9. Example of TAPE6 Output (continued)

```
                                        OLD  AFTERBODY MAPS

                  CD38 INPUT MAP

                                        AFTERBODY DRAG TABLE

 TABLEAB  NUMBER OF X-POINTS=      8.  NUMBER OF Y-POINTS=      5.
   2.180   2.500   3.330   5.000   7.430
    .400    .900   1.130   1.200   1.400   1.600   2.000   2.300
    .037    .037    .096    .064    .065    .055    .045    .042
    .048    .048    .107    .085    .072    .063    .053    .048
    .064    .064    .136    .122    .094    .081    .066    .060
    .075    .075    .180    .158    .120    .103    .085    .077
    .083    .083    .220    .200    .148    .122    .100    .090

                  AFTERBODY MAP DERIVATIVE PARAMETERS
 PARAMETER NUMBER           PARAMETER DEFINITION           OLD VALUE

         1          NOZZLE STATIC PRESSURE RATIO                1.0000
         2          TAIL FIN CONFIGURATION                      2.0000
         3          TAIL FIN ANGLE(DEG)                         0.0000
         4          TAIL FIN FORE AND AFT LOCATION RATIO         .1736
         5          BASE AREA RATIO                             0.0000

 THE FOLLOWING ARE THE TABLES OF STATION(IN) VERSUS AREA(SQFT)

           TABLE NUMBER =  1           A10/A9 =    2.18
                                 STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00  20.50

           TABLE NUMBER =  2           A10/A9 =    2.50
                                 STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00  17.84

           TABLE NUMBER =  3           A10/A9 =    3.33
                                 STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00  13.34

           TABLE NUMBER =  4           A10/A9 =    5.00
                                 STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00   8.92

           TABLE NUMBER =  5           A10/A9 =    7.43
                                 STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00   6.00
```

Figure 9. Example of TAPE6 Output (continued)

NEW AFTERBODY MAPS

CD2R INPUT MAP

AFTERBODY DRAG TABLE

TABLEAB NUMBER OF X-POINTS= 8. NUMBER OF Y-POINTS= 5.

2.180	2.500	1.330	5.000	7.430			
.400	.900	1.130	1.200	1.400	1.600	2.000	2.300
.093	.093	.153	.132	.100	.083	.066	.059
.104	.104	.164	.143	.107	.091	.076	.065
.120	.120	.195	.170	.129	.109	.087	.077
.131	.131	.237	.206	.155	.131	.106	.094
.181	.302	.507	.487	.473	.489	.558	.618

AFTERBODY DRAG CORRECTION

TABLEAD NUMBER OF X POINTS = 5 NUMBER OF Y POINTS = 5 NUMBER OF Z POINTS = 4

2.180	3.930	5.680	7.430	
.400	.875	1.350	1.825	2.300
.500	1.000	1.500	2.000	3.000
.105	0.000	-.105	-.210	-.420
.114	0.000	-.114	-.227	-.455
.068	0.000	-.068	-.137	-.274
.015	-.000	-.015	-.030	-.061
.002	0.000	-.002	-.004	-.009
.036	-0.000	-.036	-.071	-.143
.039	0.000	-.039	-.077	-.155
.023	0.000	-.023	-.047	-.093
.005	0.000	-.005	-.010	-.021
.001	0.000	-.001	-.001	-.003
.024	-.000	-.024	-.048	-.096
.026	-.000	-.026	-.052	-.104
.016	-.000	-.016	-.031	-.063
.003	-.000	-.003	-.007	-.014
.000	0.000	-.000	-.001	-.002
.024	0.000	-.024	-.047	-.095
.026	0.000	-.026	-.051	-.103
.015	-.000	-.015	-.031	-.062
.003	-.000	-.003	-.007	-.014
.000	-.000	-.000	-.001	-.002

AFTERBODY MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	NEW VALUE
1	NOZZLE STATIC PRESSURE RATIO	1.0000
2	TAIL FIN CONFIGURATION	2.0000
3	TAIL FIN ANGLE(DEG)	0.0000
4	TAIL FIN FORE AND AFT LOCATION RATIO	.3000
5	BASE AREA RATIO	.1000

Figure 9. Example of TAPE6 Output (continued)

```
THE FOLLOWING ARE THE TABLES OF STATION(IN) VERSUS AREA(SQFT)

          TABLE NUMBER =  1           A10/A9 =    2.18
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00  20.50

          TABLE NUMBER =  2           A10/A9 =    2.50
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00  17.84

          TABLE NUMBER =  3           A10/A9 =    3.33
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00  13.39

          TABLE NUMBER =  4           A10/A9 =    5.00
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00   8.92

          TABLE NUMBER =  5           A10/A9 =    7.43
                               STATION AND AREA
637.00  44.50 700.00  43.00 760.00  40.00 800.00  36.00 820.00  30.00
830.00  33.00 876.00   6.00
```

Figure 9. Example of TAPE6 Output (continued)

OLD CFG MAPS

CV1 INPUT MAP

CFG TABLE

TABLECV NUMBER OF X-POINTS= 10. NUMBER OF Y-POINTS= 7.

1.000	1.100	1.200	1.300	1.400	1.500	1.600			
1.500	2.000	3.000	4.000	5.000	6.000	8.000	10.000	14.000	18.000
.992	.992	.986	.976	.966	.955	.938	.924	.903	.886
.832	.865	.884	.886	.882	.875	.860	.847	.825	.808
.888	.935	.977	.986	.988	.983	.970	.958	.938	.920
.862	.905	.965	.982	.986	.982	.972	.964	.947	.932
.840	.890	.943	.970	[illegible]	.986	.976	.968	.954	.942
.822	.876	.932	.962	.977	.982	.978	.970	.959	.946
.800	.867	.922	.952	.970	.979	.978	.972	.961	.952

CFG MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	OLD VALUE
1	DIVERGENCE HALF ANGLE(DEG)	11.4500

Figure 9. Example of TAPE6 Output (continued)

NEW CFG MAPS

CV1 INPUT MAP

CFG TABLE

TABLECV NUMBER OF X-POINTS= 10. NUMBER OF Y-POINTS= 7.

1.020	1.100	1.200	1.300	1.400	1.500	1.600			
1.500	2.000	3.000	4.000	5.000	6.000	8.000	10.000	14.000	18.000
.992	.992	.986	.976	.966	.955	.938	.924	.903	.886
.932	.965	.984	.986	.982	.975	.960	.947	.925	.938
.887	.934	.976	.985	.987	.982	.969	.957	.937	.919
.861	.904	.964	.981	.985	.981	.971	.963	.946	.931
[illegible]	[illegible]	.945	.968	.981	.984	.974	.966	.952	.940
.820	.874	.930	.960	.975	.980	.976	.968	.957	.946
.797	.864	.919	.949	.967	.976	.975	.969	.958	.949

CFG MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	NEW VALUE
1	DIVERGENCE HALF ANGLE(DEG)	12.5000

Figure 9. Example of TAPE6 Output (concluded)

```
N>GET,DERB

N>GET,TAPE51=TEST1A,TAPE52=TEST2,TAPE53=TEST3

N>BATCH
C>DERB
           DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1    FOR INLET MAP CHANGES
 2    FOR NOZZLE/AFTBODY CHANGES
 3    FOR CV MAP CHANGES

I>1

ATS2 INLET MAP


 ENTER CODE FOR OUTPUT DESIRED
 0  FOR TAPE6 OUTPUT ONLY
 1  FOR TAPE6 OUTPUT AND TAPE1(NEW PIPSI) FILE

I>1

 INLET TYPE = TWO DIMENSIONAL

 MODE= EXTERNAL COMPRESSION
                     INLET MAP DERIVATIVE PARAMETERS
 PARAMETER NUMBER
                          PARAMETER DEFINITION                        OLD VALUE
        1          ASPECT RATIO                                         1.0000
        2          SIDEPLATE CUTBACK(ACB/ACPF)                           .2000
        3          FIRST RAMP ANGLE(DEG)                                7.0000
        4          DESIGN MACH NUMBER                                   2.0000
        5          COWL LIP BLUNTNESS                                    .0200
        6          TAKE OFF DOOR AREA RATIO                              .2000
        7          EXTERNAL COWL ANGLE(DEG)                            17.5000
        8          EXIT NOZZLE TYPE FOR BLEED(CN=0,CND=1)               1.0000
        9          EXIT NOZZLE ANGLE FOR BLEED(DEG)                    15.0000
       10          EXIT FLAP ASPECT RATIO FOR BLEED                     2.0000
       11          EXIT FLAP AREA RATIO FOR BLEED                        .1000
       12          EXIT NOZZLE TYPE FOR BYPASS(CN=0,CND=1)              1.0000
       13          EXIT NOZZLE ANGLE FOR BYPASS(DEG)                   15.0000
       14          EXIT FLAP ASPECT RATIO FOR BYPASS                    2.0000
       15          EXIT FLAP AREA RATIO FOR BYPASS                       .2000
       16          SUBSONIC DIFFUSER AREA RATIO                         1.5000
       17          SUBSONIC DIFFUSER TOTAL WALL ANGLE(DEG)             10.0000
       18          SUBSONIC DIFFUSER LOSS COEFFICIENT                    .1000
```

Figure 10. Example of a Typical Terminal Session

```
 INPUT NUMBER OF PARAMETERS TO BE CHANGED

I>4

 INPUT THE PARAMETERS TO BE CHANGED FOLLOWED BY THE
  NEW VALUES IN PAIRS(PARAMETER NUMBER,NEW VALUE)

I>1 .95 4 2.5 5 .03 18 .12
 PARAMETER NUMBER              PARAMETER DEFINITION                      NEW VALUE
         1              ASPECT RATIO                                       .9500
         4              DESIGN MACH NUMBER                                2.5000
         5              COWL LIP BLUNTNESS                                 .0300
        18              SUBSONIC DIFFUSER LOSS COEFFICIENT                 .1200

 ARE THE DERIVATIVE PARAMETERS CORRECT(0=YES  1=NO)

I>0
           DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1   FOR INLET MAP CHANGES
 2   FOR NOZZLE/AFTBODY CHANGES
 3   FOR CV MAP CHANGES

I>2

CD2R INPUT MAP


 ENTER CODE FOR OUTPUT DESIRED
 0  FOR TAPE6 OUTPUT ONLY
 1  FOR TAPE6 OUTPUT AND TAPE1(NEW FIRST) FILE

I>1

 AFTERBODY TYPE = CD-AXISYMMETRIC DUAL NOZZLE
                         AFTERBODY MAP DERIVATIVE PARAMETERS
 PARAMETER NUMBER              PARAMETER DEFINITION                      OLD VALUE
         1              NOZZLE STATIC PRESSURE RATIO                      1.0000
         2              TAIL FIN CONFIGURATION                            2.0000
         3              TAIL FIN ANGLE(DEG)                               0.0000
         4              TAIL FIN FORE AND AFT LOCATION RATIO               .1736
         5              BASE AREA RATIO                                   0.0000

 INPUT NUMBER OF PARAMETERS TO BE CHANGED

I>1
```

Figure 10. Example of a Typical Terminal Session (continued)

```
INPUT THE PARAMETERS TO BE CHANGED FOLLOWED BY THE
NEW VALUES IN PAIRS(PARAMETER NUMBER, NEW VALUE)

I>5 .1
PARAMETER NUMBER                PARAMETER DEFINITION                  NEW VALUE
       5           BASE AREA RATIO                                     .1000

ARE DERIVATIVE PARAMETERS CORRECT(0=YES  1=NO)

I>0

THE FOLLOWING ARE THE OLD TABLES(STATION(IN) VERSUS AREA(SQFT))
ASSOCIATED WITH A PARTICULAR A10/A9
THE USER MAY CHANGE A TABLE VALUE FOR A
PARTICULAR A10/A9 RATIO


           TABLE NUMBER =  1    A10/A9 =     2.18
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00  20.50

           TABLE NUMBER =  2    A10/A9 =     2.50
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00  17.84

           TABLE NUMBER =  3    A10/A9 =     3.33
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00  13.39

           TABLE NUMBER =  4    A10/A9 =     5.00
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00   8.92

           TABLE NUMBER =  5    A10/A9 =     7.43
                               STATION AND AREA
637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
830.00  20.50 876.00   6.00

DO YOU WISH TO CHANGE A TABLE (0=NO 1=YES)

I>0
DO YOU WISH TO CHANGE THE DEFAULT A9A8 SCHEDULE(0=NO  1=YES)

I>0
```

Figure 10. Example of a Typical Terminal Session (continued)

```
          DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1   FOR INLET MAP CHANGES
 2   FOR NOZZLE/AFTBODY CHANGES
 3   FOR CV MAP CHANGES

I>3

CV: INPUT MAP


 ENTER CODE FOR OUTPUT DESIRED
 0  FOR TAPE6 OUTPUT ONLY
 1  FOR TAPE6 OUTPUT AND TAPE1(NEW PIPSI) FILE

I>1

 NOZZLE TYPE = ROUND CONVERGENT-DIVERGENT NOZZLE
                      CFG MAP DERIVATIVE PARAMETERS
 PARAMETER NUMBER              PARAMETER DEFINITION                   OLD VALUE
        1          DIVERGENCE HALF ANGLE(DEG)                          11.4500

 INPUT NUMBER OF PARAMETERS TO BE CHANGED

I>1

 INPUT THE PARAMETERS TO BE CHANGED FOLLOWED
 BY THE NEW VALUE IN PAIRS(PARAMETER NUMBER,NEW VALUE)

I>1 12.5
 PARAMETER NUMBER              PARAMETER DEFINITION                   NEW VALUE
        1          DIVERGENCE HALF ANGLE(DEG)                          12.5000

 ARE THE DERIVATIVE PARAMETERS CORRECT(0=YES  1=NO)

I>0
          DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1   FOR INLET MAP CHANGES
 2   FOR NOZZLE/AFTBODY CHANGES
 3   FOR CV MAP CHANGES

I>"END"
```

Figure 10. Example of a Typical Terminal Session (concluded)

If the user does not wish to continue, at this point a response of "END" will discontinue execution of the program.

When the option is selected, the name of the file which is the first card on the disk file is printed to inform the user of the type of file being used.

4.3.2 Output Code Type

The user at this time selects the type of output desired from the program. The options are:

0 TAPE 6 output only
1 TAPE 6 plus TAPE1 (a new PIPSI file)

Once the output code has been selected, the derivative parameters are listed at the terminal. Only the derivative parameters actually required for this input map file are listed and are modifiable.

4.3.3 Number of Parameters to be Changed

The user looks at the list of derivative parameters and decides how many are to be changed. That number is entered in response to the prompt.

4.3.4 Input of New Parameter Values

The user inputs the parameter number and parameter value in pairs for the parameters to be changed. The results are listed on the terminal for the user to review to see if they are correct.

4.3.5 Is Input Correct Code

If the above input has been correct, the user will enter a zero; if not the user will enter a one and the sequence of prompts and responses will be repeated. At this point, also, the user may enter "END" and the program will be terminated. After a zero has been entered for this prompt, the program executes and the next prompt will be the map type code prompt discussed in 4.3.1, at which time the user may execute another case or terminate execution.

4.4 Program Execution Sequence

In order to execute the Derivative Processor, the user must attach all disk files which are expected to be used to specific file names recognized by the program. These are:

TAPE 51 = Inlet file name.
TAPE 52 = Nozzle/afterbody drag file name.
TAPE 53 = Nozzle thrust coefficient file name.

A typical set of control cards is shown below:

```
ATTACH, TAPE 51 = ATS2DP2.
ATTACH, TAPE 52 = CD2R.
ATTACH, TAPE 53 = CV1.
```

where ATS2DP2, CD2R and CV1 are previously constructed files existing on the user permanent files.

The user then attaches the Derivative Processor program,

ATTACH, DERIVP = existing permanent file name of an absolute binary file of the program.

It should be noted here that a pre-existing absolute file must have been generated and saved from a compilation and load of the program. This is necessary in order that the program be able to run in less than 60K octal words in an interactive environment.

```
DERIVP
```

This executes the program and is the absolute overlay file name and must be used when executing the absolute file. The user then responds to prompts once the program is executing. After an "END" is entered, the program terminates execution. At this time the user may elect to perform different types of outfile manipulations, such as saving, listing, disposing, or merging.

SECTION V
SAMPLE CASES

The purpose of the sample cases for the derivative procedure is to demonstrate the major flow paths in the program used to produce new inlet and nozzle/aftbody maps. Three sample sets are provided for the derivative procedure program. One set will be used to demonstrate the major flow paths used to produce a new inlet map, the second sample set will be used to demonstrate the flow paths used to produce a new nozzle/aftbody drag map, and the third set will be used to demonstrate the flow paths used to produce a new nozzle internal performance (C_{F_G}) map.

Each of the sample cases is described separately in the sections which follow. For each of the sample cases, the following information is provided:

(1) Old (baseline) input data tables and baseline derivative parameters for which the data tables correspond.

(2) A list of new derivative parameters for which a new (perturbed) map is to be produced.

(3) a set of terminal input commands used to interactively generate the new set of input data tables.

(4) A new set of input tables produced by the derivative procedure program.

5.1 INLET DERIVATIVE PROCEDURE SAMPLE CASE

The baseline inlet used to demonstrate the inlet derivative procedure is Configuration #8, File Name ATS2. The inlet is an external compression, four-shock inlet designed for a free-stream Mach number of 2.0. The inlet has two movable external ramps, a 7.3^{o} initial ramp angle, a

boundary layer control bleed system consisting of porous bleed on the second and third ramp surfaces and sideplates; and a throat bleed slot located aft of the normal shock. The throat slot also acts as a bypass to remove excess inlet airflow for matching engine airflow demand with inlet supply. The inlet characteristics were built up from engineering analyses and available data from similar configurations and components. A sketch of the configuration is shown in Figure 11.

The predicted inlet performance characteristics for the ATS2 inlet are shown plotted in figures 12 through 21. These performance characteristics are entered as old (baseline) data tables (Figure 22).

Each set of inlet input tables in the library is accompanied by a set of derivative parameters that describe the configuration in terms of its important variables. An example showing the derivative parameters for the ATS2 inlet is presented in Figure 23. In addition to the complete set of derivative parameters for the library inlet configuration, a new set of inlet derivative parameters must be input by the user to specify the new values of the parameters that are to be used in the new configuration calculations. The new derivative parameters for the ATS2 inlet test case are shown in Figure 24.

The set of interactive terminal commands input by the user to run the inlet derivative procedure program is presented in Figure 25.

The output file obtained as a result of the ATS2 inlet sample case run is presented in Figure 26. The old (original library configuration) inlet maps are printed out first together with the original derivative parameters. Next, the new set of inlet maps is printed out, with the new set of derivative parameters shown for reference.

5.2 NOZZLE/AFTBODY DRAG DERIVATIVE PROGRAM SAMPLE CASE

The baseline nozzle/aftbody configuration used to demonstrate the operation of the nozzle/aftbody drag map derivative procedure is the twin,

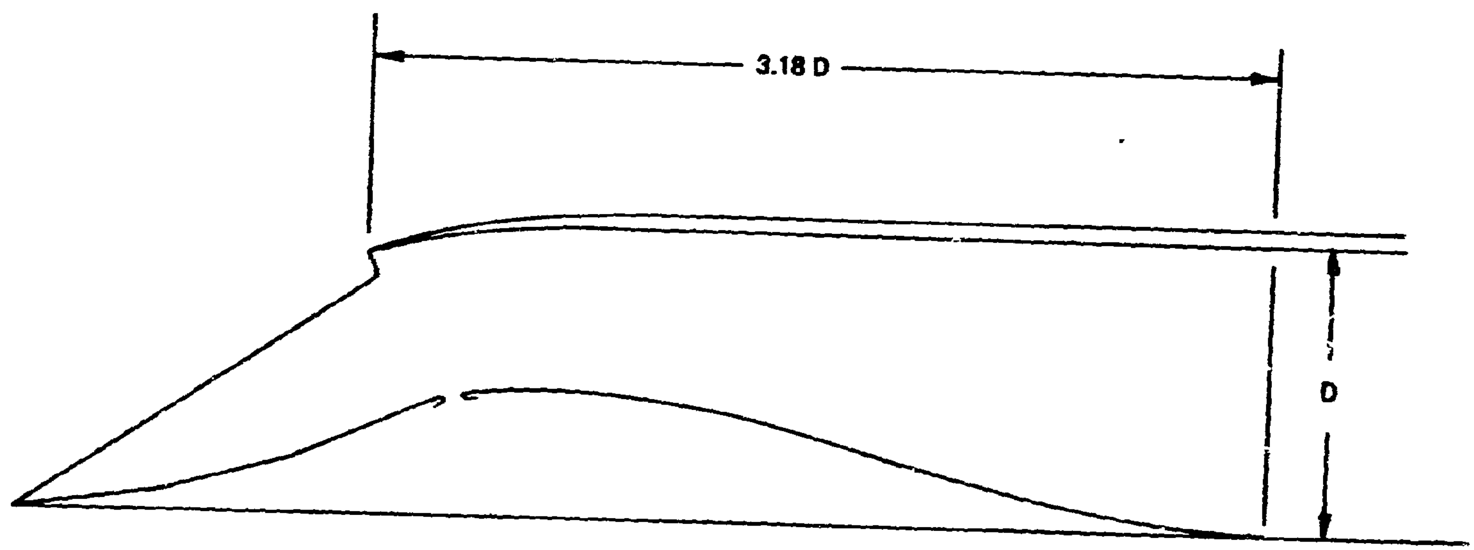


Figure 11. ATS2 Inlet

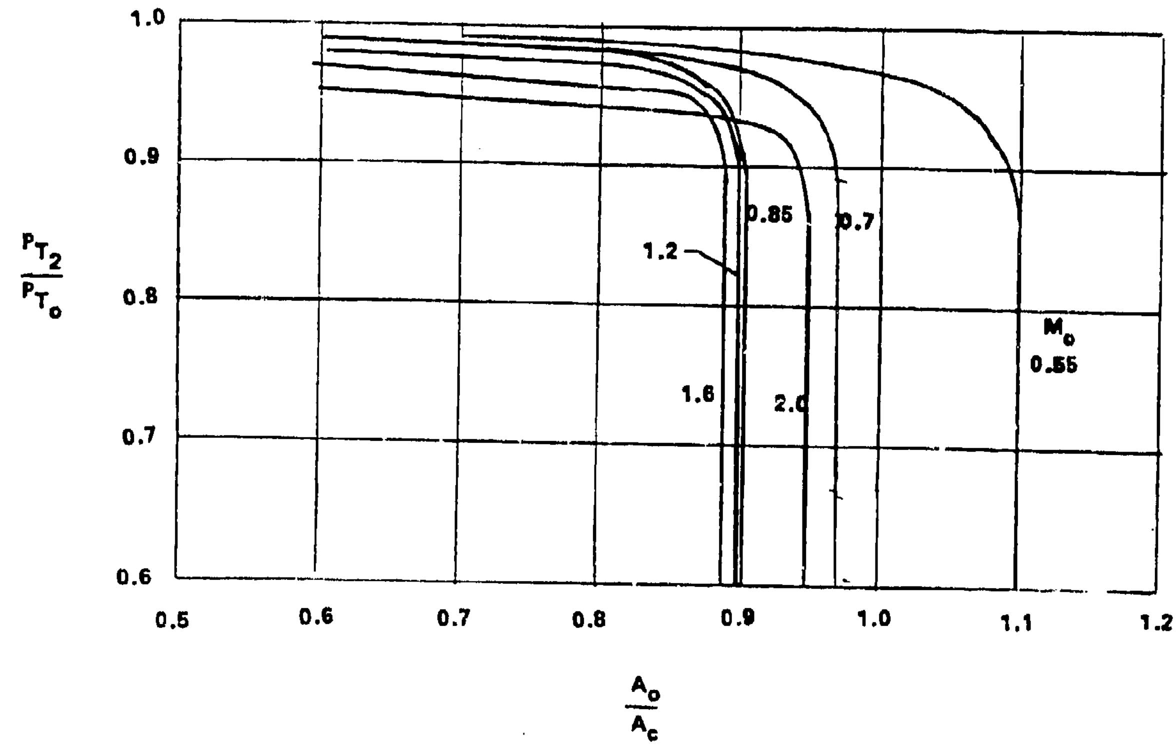


Figure 12. Total Pressure Recovery vs. Mass Flow Ratio

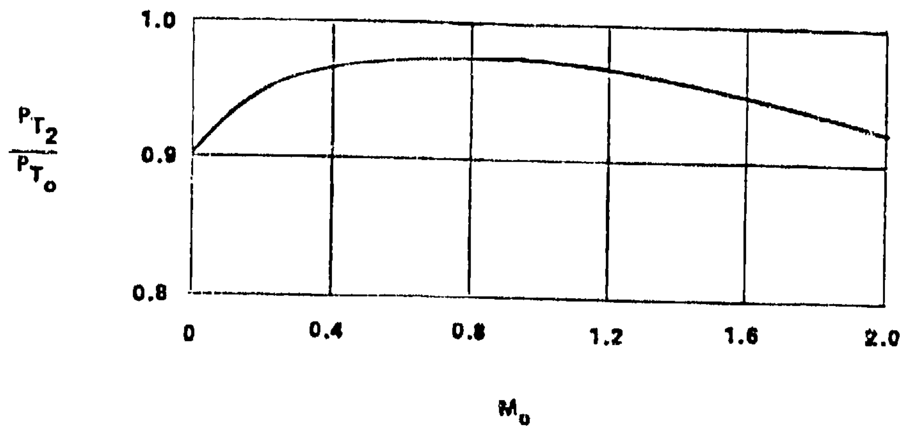


Figure 13. Matched Total Pressure Recovery

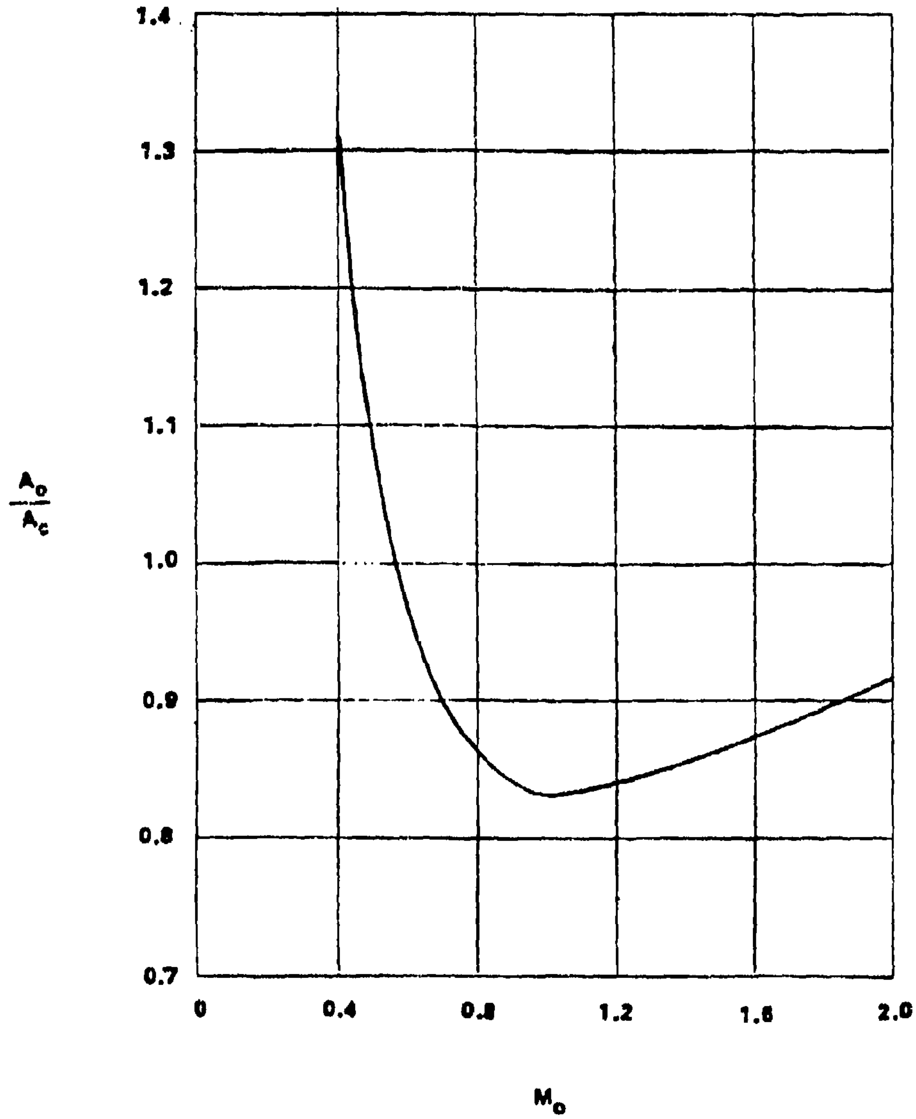


Figure 14. Matched Inlet Mass Flow Ratio

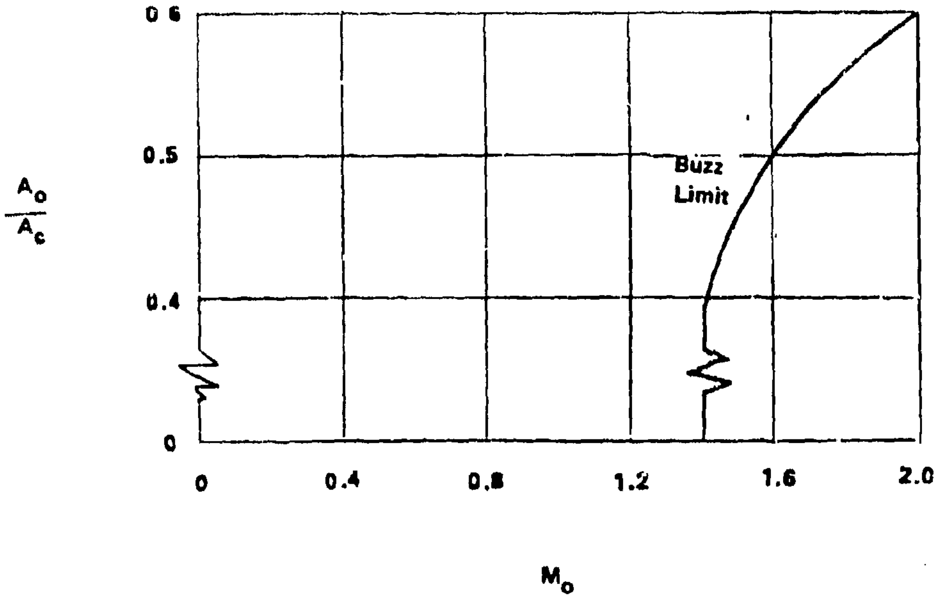


Figure 15. Buzz Limit Mass Flow Ratio

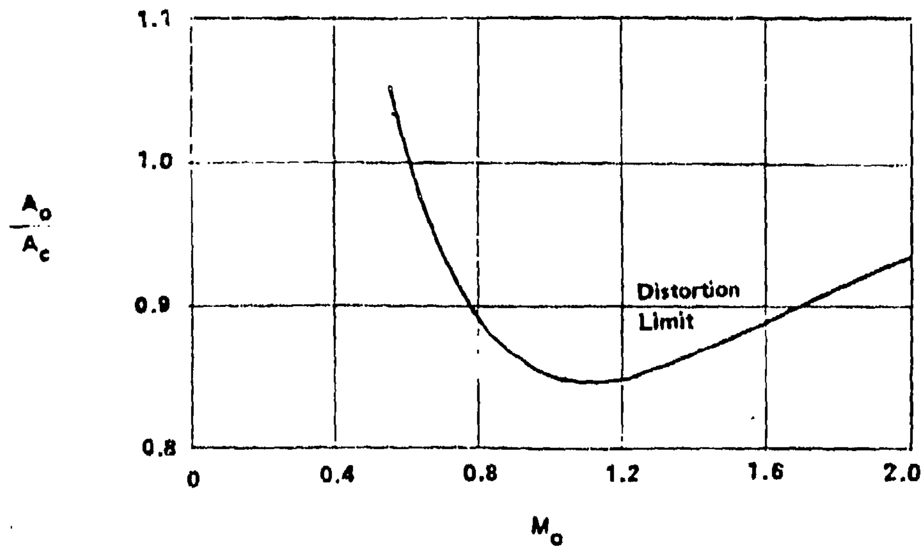


Figure 16. Distortion Limit Mass Flow Ratio

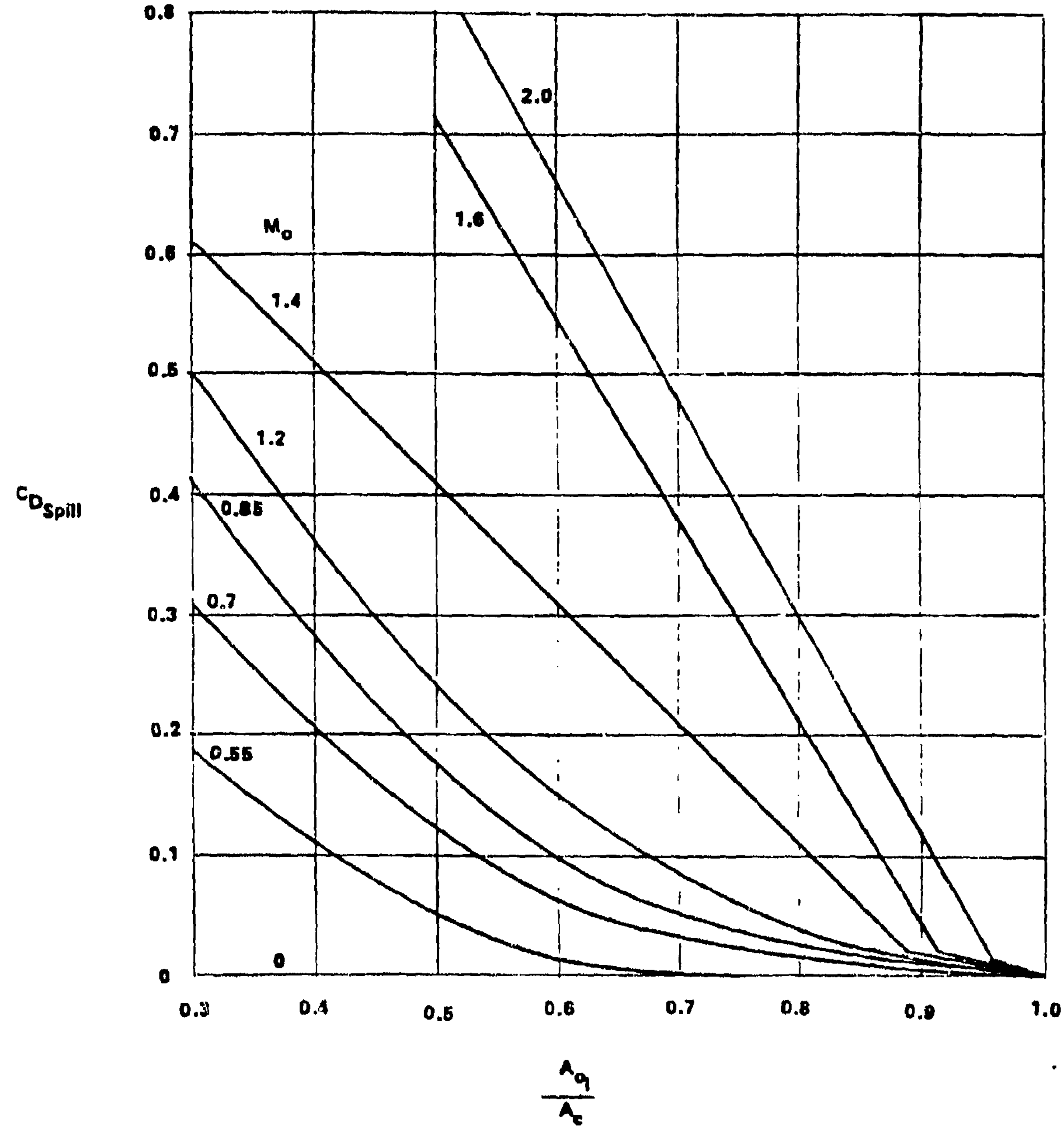
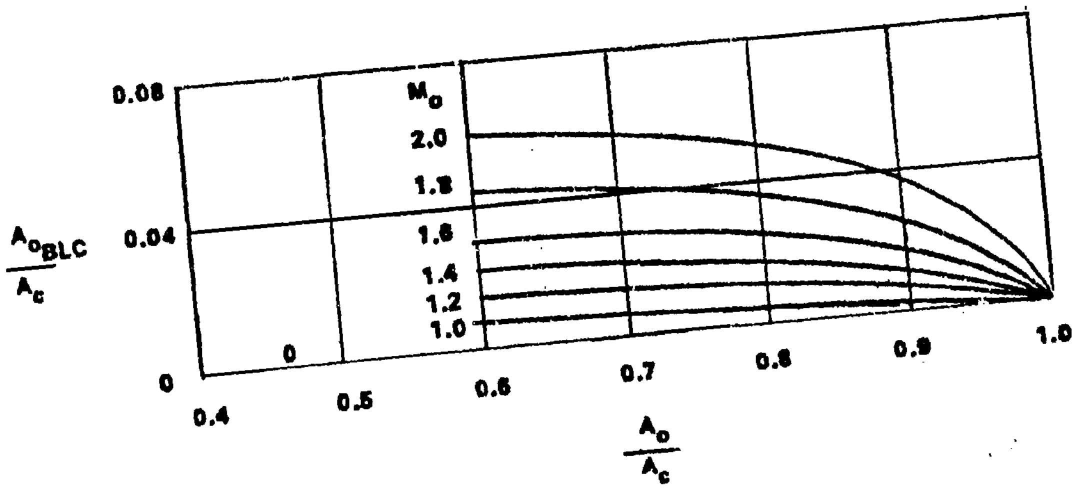
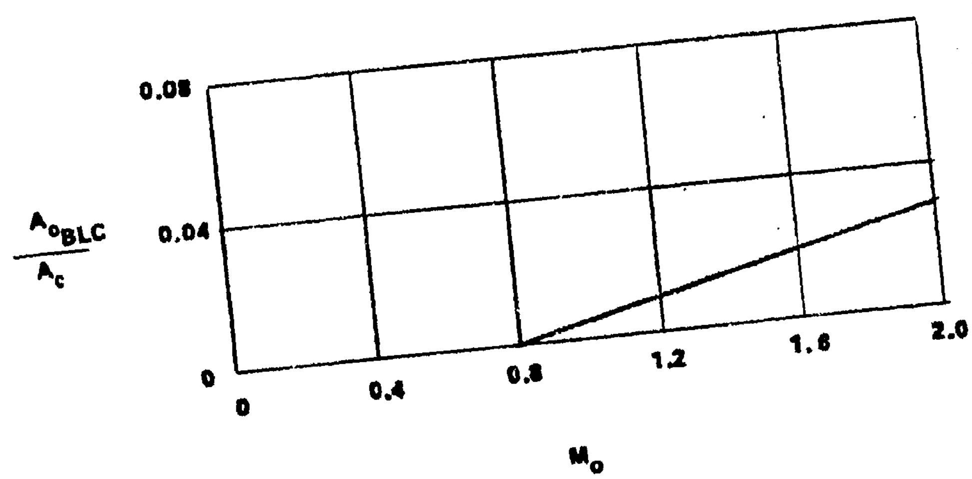


Figure 17. Spillage Drag vs. Inlet Mass Flow Ratio



(a) $A_{o_{BLC}}/A_c$ vs. A_o/A_c



(b) Matched $A_{o_{BLC}}/A_c$ vs. M_o

Figure 18. Reference Spillage Drag and Mass Flow Ratio

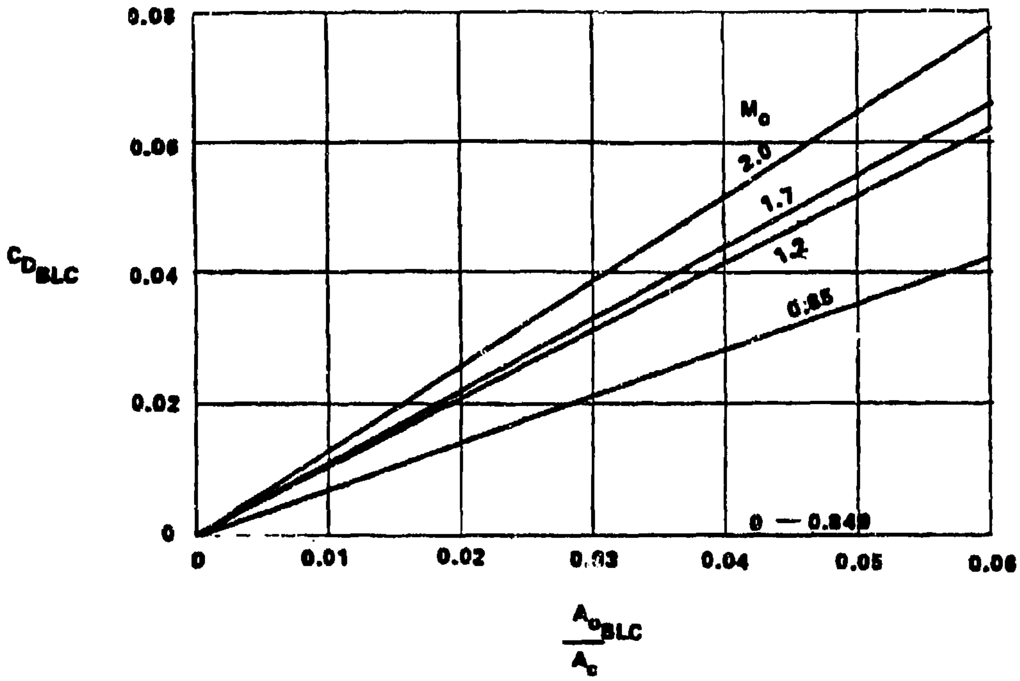


Figure 19. Boundary Layer Bleed Drag vs. Bleed Mass Flow Ratio

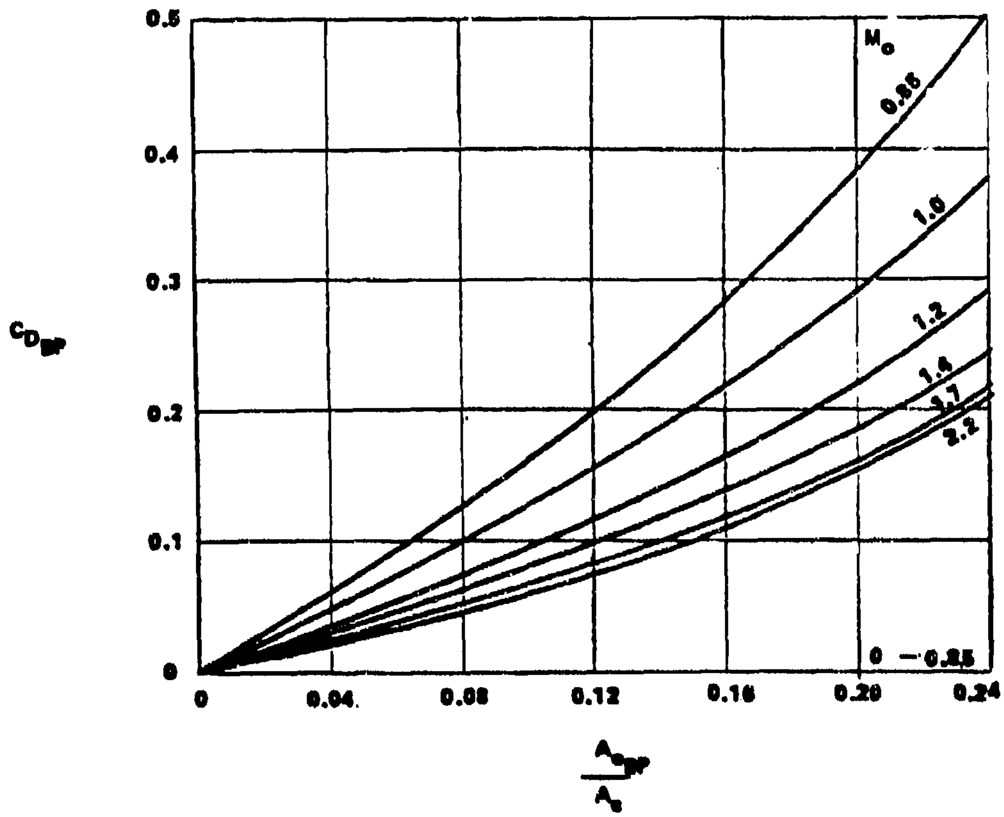


Figure 20. Bypass Drag vs. Bypass Mass Flow Ratio

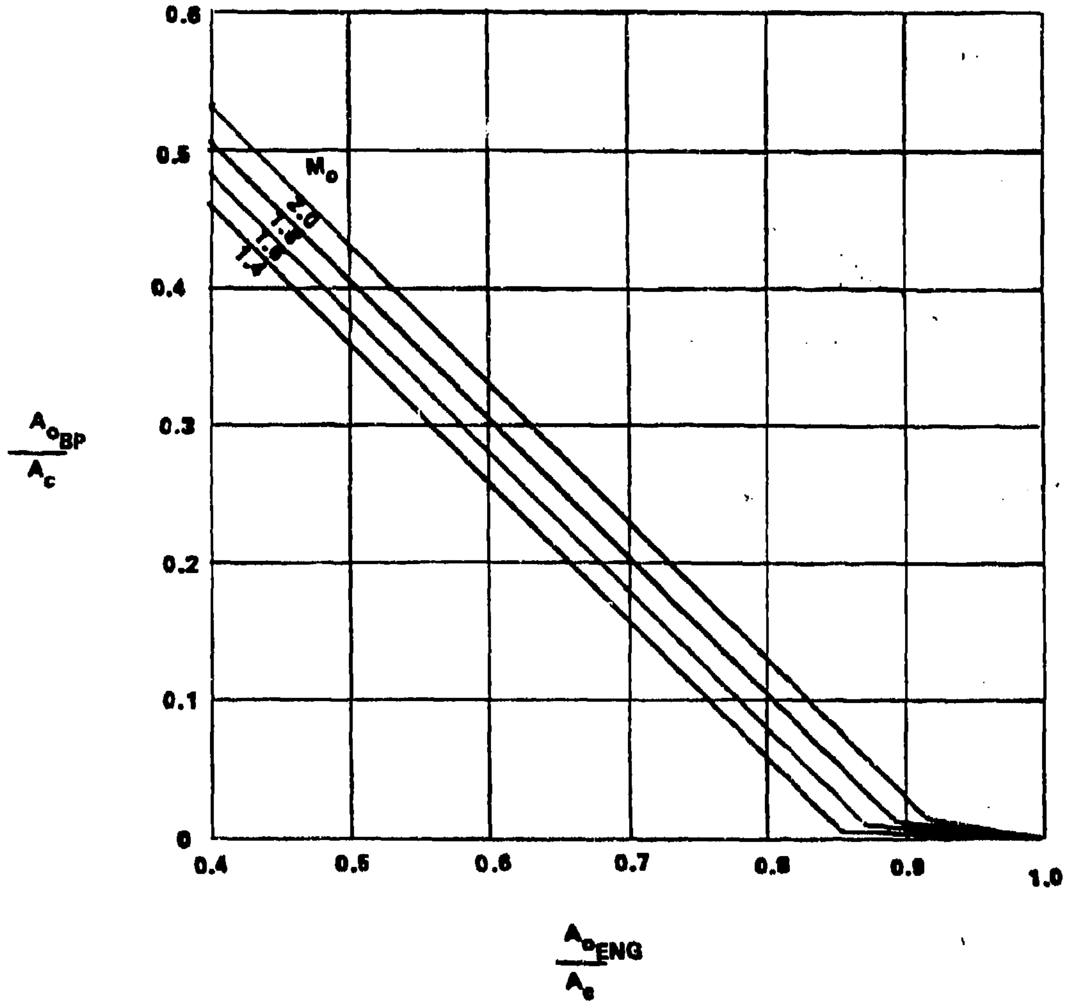


Figure 21. Bypass Mass Flow Ratio vs. Engine Demand Mass Flow Ratio

```
ATS2 INLET MAP
   .95     .20    7.30    2.50     .03     .20   17.50    1.00   15.00    2.00
   .10    1.00   15.00    2.00     .20    0.00    0.00     .12    0.06
  1.00    1.25    3.00     .75    1.00
TABLE1    3.
 0.000    .200   2.500
 0.000    .200   2.500
TABLE2A   6.
 7.000   6.000   7.000   7.000   8.000   9.000
  .550    .700    .850   1.300   1.900   2.500
  .559    .639    .719    .799    .843    .859    .879
  .990    .990    .984    .968    .949    .932    .874
  .480    .560    .639    .719    .759    .779
  .989    .989    .984    .973    .944    .809
  .399    .479    .559    .639    .679    .700    .724
  .988    .988    .987    .981    .973    .960    .808
  .416    .500    .584    .668    .710    .732    .755
  .960    .959    .957    .953    .947    .935    .880
  .453    .545    .637    .730    .776    .800    .809    .814
  .938    .937    .927    .920    .917    .902    .887    .862
  .493    .594    .694    .794    .896    .926    .932    .940    .947
  .898    .893    .880    .886    .875    .865    .860    .840    .790
TABLE2B   9.
 0.000    .200    .400    .600    .900   1.000   1.300   1.900   2.500
  .692    .848    .963    .971    .975    .969    .947    .910    .865
TABLE2C   7.
  .400    .600    .900   1.000   1.300   1.900   2.500
 1.046    .774    .690    .664    .702    .798    .915
TABLE2D   6.
 0.000   1.599   1.600   1.900   2.700   2.500
 0.000   0.000    .755    .755    .814    .914
TABLE2E   6.
  .550    .700    .900   1.300   1.900   2.500
  .282    .480    .399    .416    .453    .493
TABLE3    9.
 3.000   3.000   7.000   9.000   9.000   7.000   7.000   7.000   7.000
 0.000    .549    .550    .700    .850   1.300   1.600   1.900   2.500
 0.000    .798   1.000
 0.000   0.000   0.000
 0.000    .798   1.000
 0.000   0.000   0.000
  .240    .320    .399    .479    .559    .572   1.000
  .157    .096    .048    .011    .002   0.000   0.000
  .240    .320    .400    .480    .560    .639    .719    .759   1.000
  .255    .171    .103    .053    .029    .014    .003   0.000   0.000
  .240    .320    .400    .480    .560    .640    .720    .770   1.000
  .336    .231    .145    .082    .043    .023    .009   0.000   0.000
  .252    .335    .419    .503    .587    .671    .755    .804   1.000
  .442    .320    .215    .135    .078    .035    .013   0.000   0.000
  .264    .439    .615    .703    .779    .798   1.000
  .764    .456    .225    .120    .025   0.000   0.000
  .459    .551    .643    .734    .943    .952   1.000
  .766    .593    .402    .230    .023   0.000   0.000
  .500    .699    .797    .899    .956    .961   1.000
  .925    .535    .333    .132    .010   0.000   0.000
```

Figure 22. ATS2 Inlet Input Data Tables

```
TABLE3A      3.
   0.000  1.000  2.500
   0.000  0.000  0.000
TABLE3B      3.
   0.000  1.000  2.500
    .999   .999   .999
TABLE4       5.     6.
   0.000   .849   .850  1.300  2.050  2.500
   0.000   .011   .022   .044   .066
   0.000  0.000  0.000  0.000  0.000
   0.000  0.000  0.000  0.000  0.000
   0.000   .007   .014   .029   .042
   0.000   .010   .021   .042   .052
   0.000   .011   .022   .044   .066
   0.000   .011   .023   .046   .068
TABLE5       7.     8.
   0.000   .849   .950  1.000  1.300  1.600  2.050  2.800
   0.000   .042   .083   .125   .166   .208   .249
   0.000  0.000  0.000  0.000  0.000  0.000  0.000
   0.000  0.000  0.000  0.000  0.000  0.000  0.000
   0.000   .062   .125   .198   .280   .380   .500
   0.000   .050   .100   .156   .217   .290   .375
   0.000   .036   .075   .117   .161   .217   .285
   0.000   .030   .062   .096   .133   .181   .234
   0.000   .026   .055   .084   .120   .164   .220
   0.000   .023   .051   .083   .123   .170   .233
TABLE6A      8.
   2.000  2.000  5.000  5.000  5.000  6.000  6.000  6.000
   0.000   .800  1.000  1.300  1.600  1.900  2.200  2.500
   -.000   .797
   0.000  0.000
   -.001   .800
   0.000  0.000
    .486   .567   .674   .731   .812
    .009   .009   .005   .003  0.000
    .500   .584   .702   .753   .838
    .015   .014   .011   .009  0.000
    .522   .611   .751   .788   .873
    .024   .022   .015   .013  0.000
    .545   .637   .730   .805   .851   .917
    .033   .032   .028   .022   .015  0.000
    .570   .666   .742   .865   .888   .958
    .048   .046   .041   .027   .023  0.000
    .594   .694   .794   .884   .926   .999
    .066   .061   .055   .041   .033  0.000
TABLE6B      5.
   0.000   .800  1.300  1.900  2.500
   0.000  0.000   .011   .022   .033
TABLE7       6.
   2.000  2.000  4.000  4.000  4.000  4.000
   0.000  1.599  1.600  1.900  2.200  2.500
   0.000  1.000
   0.000  0.000
   0.000  1.000
   0.000  0.000
    .350   .748   .752  1.000
    .404   .004  0.000  0.000
    .366   .798   .807  1.000
    .442   .009  0.000  0.000
    .383   .855   .868  1.000
    .485   .013  0.000  0.000
    .400   .915   .930  1.000
    .532   .015  0.000  0.000
```

Figure 22. ATS2 Inlet Input Data Tables (concluded)

INLET TYPE = TWO DIMENSIONAL

MODE= EXTERNAL COMPRESSION

INLET MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	OLD VALUE
1	ASPECT RATIO	1.0000
2	SIDEPLATE CUTBACK	.2000
3	FIRST RAMP ANGLE(DEG)	7.3000
4	DESIGN MACH NUMBER	2.0000
5	COWL LIP BLUNTNESS	.0200
6	TAKE OFF DOOR AREA	.2000
7	EXTERNAL COWL ANGLE(DEG)	17.5000
8	EXIT NOZZLE TYPE FOR BLEED	1.0000
9	EXIT NOZZLE ANGLE FOR BLEED(DEG)	15.0000
10	EXIT FLAP ASPECT RATIO FOR BLEED	2.0000
11	EXIT FLAP AREA FOR BLEED	.1000
12	EXIT NOZZLE TYPE FOR BYPASS	1.0000
13	EXIT NOZZLE ANGLE FOR BYPASS(DEG)	15.0000
14	EXIT FLAP ASPECT RATIO FOR BYPASS	2.0000
15	EXIT FLAP AREA FOR BYPASS	.2000
16	SUBSONIC DIFFUSER AREA RATIO	1.5000
17	SUBSONIC DIFFUSER TOTAL WALL ANGLE(DEG)	10.0000
18	SUBSONIC DIFFUSER LOSS COEFFICIENT	.1000

Figure 23. Old Inlet Derivative Parameters

PARAMETER NUMBER	PARAMETER DEFINITION	NEW VALUE
1	ASPECT RATIO	.9500
4	DESIGN MACH NUMBER	2.5000
5	COWL LIP BLUNTNESS	.0300
18	SUBSONIC DIFFUSER LOSS COEFFICIENT	.1200

Figure 24. New Inlet Derivative Parameters

```
N>GET,DERB

N>GET,TAPE51=TEST1A,TAPE52=TEST2,TAPE53=TEST3

N>BATCH
C>DERB
           DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1   FOR INLET MAP CHANGES
 2   FOR NOZZLE/AFTBODY CHANGES
 3   FOR CV MAP CHANGES

I>1

ATS2 INLET MAP


 ENTER CODE FOR OUTPUT DESIRED
 0  FOR TAPE6 OUTPUT ONLY
 1  FOR TAPE6 OUTPUT AND TAPE1(NEW PIPSI) FILE

I>1

 INLET TYPE = TWO DIMENSIONAL

 MODE= EXTERNAL COMPRESSION
                    INLET MAP DERIVATIVE PARAMETERS
 PARAMETER NUMBER            PARAMETER DEFINITION                  OLD VALUE
        1          ASPECT RATIO                                      1.0000
        2          SIDEPLATE CUTBACK(ACB/ASPF)                        .2000
        3          FIRST RAMP ANGLE(DEG)                             7.3000
        4          DESIGN MACH NUMBER                                2.0000
        5          COWL LIP BLUNTNESS                                 .0200
        6          TAKE OFF DOOR AREA RATIO                           .2000
        7          EXTERNAL COWL ANGLE(DEG)                         17.5000
        8          EXIT NOZZLE TYPE FOR BLEED(CN=0,CND=1)            1.0000
        9          EXIT NOZZLE ANGLE FOR BLEED(DEG)                 15.0000
       10          EXIT FLAP ASPECT RATIO FOR BLEED                  2.0000
       11          EXIT FLAP AREA RATIO FOR BLEED                     .1000
       12          EXIT NOZZLE TYPE FOR BYPASS(CN=0,CND=1)           1.0000
       13          EXIT NOZZLE ANGLE FOR BYPASS(DEG)                15.0000
       14          EXIT FLAP ASPECT RATIO FOR BYPASS                 2.0000
       15          EXIT FLAP AREA RATIO FOR BYPASS                    .2000
       16          SUBSONIC DIFFUSER AREA RATIO                      1.5000
       17          SUBSONIC DIFFUSER TOTAL WALL ANGLE(DEG)          10.0000
       18          SUBSONIC DIFFUSER LOSS COEFFICIENT                 .1000
```

Figure 25. Terminal Input Commands for Inlet Derivative Program

```
INPUT NUMBER OF PARAMETERS TO BE CHANGED

I>4

INPUT THE PARAMETERS TO BE CHANGED FOLLOWED BY THE
 NEW VALUES IN PAIRS(PARAMETER NUMBER,NEW VALUE)

I>1 .95 4 2.5 5 .03 18 .12
PARAMETER NUMBER             PARAMETER DEFINITION                    NEW VALUE
       1          ASPECT RATIO                                           .9500
       4          DESIGN MACH NUMBER                                    2.5000
       5          COWL LIP BLUNTNESS                                     .0300
      18          SUBSONIC DIFFUSER LOSS COEFFICIENT                     .1200

ARE THE DERIVATIVE PARAMETERS CORRECT(0=YES  1=NO)

I>0
          DERIVATIVE PROCEDURE PROGRAM

ENTER CODE FOR MAPS TO BE CHANGED
1   FOR INLET MAP CHANGES
2   FOR NOZZLE/AFTBODY CHANGES
3   FOR CV MAP CHANGES

I>2

CD2R INPUT MAP


ENTER CODE FOR OUTPUT DESIRED
0  FOR TAPE6 OUTPUT ONLY
1  FOR TAPE6 OUTPUT AND TAPE1(NEW PIPSI) FILE

I>1

AFTERBODY TYPE = CD-AXISYMMETRIC DUAL NOZZLE
                    AFTERBODY MAP DERIVATIVE PARAMETERS
PARAMETER NUMBER             PARAMETER DEFINITION                    OLD VALUE
       1          NOZZLE STATIC PRESSURE RATIO                          1.0000
       2          TAIL FIN CONFIGURATION                                2.0000
       3          TAIL FIN ANGLE(DEG)                                   0.0000
       4          TAIL FIN FORE AND AFT LOCATION RATIO                   .1736
       5          BASE AREA RATIO                                       0.0000

INPUT NUMBER OF PARAMETERS TO BE CHANGED

I>"END"
```

Figure 25. Terminal Input Commands for Inlet Derivative Program (concluded)

```
                                                 OLD   INLET      MAPS

                    ATS2 INLET MAP


                                                 LOCAL MACH NUMBER

TABLE1    NUMBER OF POINTS =        3.
   0.000    .200   2.000
   0.000    .200   2.000

                                                 RECOVERY VS MASS FLOW

TABLE2A   NUMBER OF Y POINTS =         6.
NUMBER OF X POINTS =      7.        6.        7.        7.        8.        9.
    .550    .700    .850   1.200   1.600   2.000
    .700    .800    .900   1.009   1.055   1.075   1.100
    .992    .991    .985    .969    .950    .933    .879
    .600    .700    .800    .900    .950    .970
    .990    .990    .985    .974    .945    .900
    .500    .600    .700    .800    .850    .875    .905
    .990    .990    .989    .983    .975    .962    .900
    .500    .600    .700    .800    .850    .875    .902
    .980    .979    .977    .973    .967    .955    .900
    .500    .600    .700    .800    .850    .875    .885    .890
    .978    .970    .965    .958    .955    .940    .925    .900
    .500    .600    .700    .800    .900    .930    .935    .943    .950
    .958    .953    .949    .944    .935    .925    .920    .900    .850

                                                 MATCHED INLET RECOVERY

TABLE2B   NUMBER OF POINTS =        9.
   0.000    .200    .400    .600    .800   1.000   1.200   1.600   2.000
    .900    .950    .965    .972    .975    .975    .967    .948    .925

                                                 MATCHED MASS FLOW

TABLE2C   NUMBER OF POINTS =        7.
    .400    .600    .800   1.000   1.200   1.600   2.000
   1.310    .968    .863    .830    .840    .872    .915

                                                 BUZZ LIMIT

TABLE2D   NUMBER OF POINTS =        6.
   0.000   1.399   1.400   1.600   1.800   2.000
   0.000   0.000    .400    .500    .560    .600
```

Figure 26. Derivative Procedure Output File

```
                                                   DISTORTION LIMIT
TABLE2E   NUMBER OF POINTS =      6.
   .550    .700    .800   1.200   1.600   2.000
  1.055    .935    .890    .846    .890    .935

                                                   SPILLAGE DRAG

TABLE3    NUMBER OF Y POINTS =        9.
NUMBER OF X POINTS =      2.      2.      7.      9.      9.      9.      7.      7.      7.
  0.000    .549    .550    .700    .850   1.200   1.400   1.600   2.000
  0.000   1.000
  0.003   0.000
  0.003   1.000
  0.000   0.000
   .303    .400    .500    .600    .700    .725   1.000
   .185    .110    .052    .015    .002   0.000   0.000
   .303    .400    .500    .600    .700    .800    .900    .950   1.000
   .310    .207    .123    .062    .032    .015    .005   0.000   0.000
   .300    .400    .500    .600    .700    .800    .900    .963   1.000
   .410    .289    .179    .098    .050    .026    .010   0.000   0.000
   .300    .400    .500    .600    .700    .800    .900    .958   1.000
   .500    .360    .240    .150    .086    .038    .014   0.000   0.000
   .300    .500    .700    .800    .887    .900   1.000
   .750    .437    .210    .110    .022   0.000   0.000
   .500    .600    .700    .800    .915    .920   1.000
   .715    .550    .370    .210    .021   0.000   0.000
   .500    .700    .800    .900    .957    .962   1.000
   .840    .480    .290    .118    .010   0.000   0.000

                                                   REFERENCE SPILLAGE DRAG

TABLE3A   NUMBER OF POINTS =      3.
  0.000   1.000   2.000
  0.000   0.000   0.000

                                                   REFERENCE MASS FLOW

TABLE3B   NUMBER OF POINTS =      3.
  0.000   1.000   2.000
  1.000   1.000   1.000

                                                   BOUNDARY LAYER BLEED DRAG

TABLE4    NUMBER OF X-POINTS=      5.  NUMBER OF Y-POINTS=      6.
  0.000    .849    .850   1.200   1.700   2.000
  0.000    .010    .020    .040    .060
  0.000   0.000   0.000   0.000   0.000
  0.000   0.000   0.000   0.000   0.000
  0.000    .007    .014    .028    .042
  0.000    .010    .021    .042    .062
  0.000    .011    .022    .044    .066
  0.000    .013    .026    .052    .078
```

Figure 26. Derivative Procedure Output File (continued)

```
                                        BYPASS DRAG

TABLE5   NUMBER OF X-POINTS=      7.  NUMBER OF Y-POINTS=      8.
  0.000   .849   .850  1.000  1.200  1.400  1.700  2.200
  0.000   .940   .080   .120   .160   .200   .240
  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  0.000   .062   .125   .190   .280   .380   .500
  0.000   .050   .100   .156   .217  -.290   .375
  0.000   .036   .075   .117   .162   .220   .290
  0.000   .030   .062   .097   .135   .185   .241
  0.000   .025   .052   .081   .116   .160   .216
  0.000   .020   .045   .074   .110   .153   .210

                                        BOUNDARY LAYER BLEED DRAG

TABLE6A  NUMBER OF Y POINTS =      8.
NUMBER OF X POINTS =     2.     2.     5.     5.     5.     6.     6.     6.
  0.000   .900  1.000  1.200  1.400  1.600  1.800  2.000
  0.000  1.000
  0.000  0.000
  0.000  1.000
  0.000  0.000
   .600   .700   .831   .900  1.000
   .008   .007   .005   .003  0.000
   .600   .700   .840   .900  1.000
   .014   .013   .010   .008  0.000
   .600   .700   .859   .900  1.000
   .022   .020   .015   .012  0.000
   .600   .700   .800   .881   .930  1.000
   .030   .029   .026   .020   .014  0.000
   .600   .700   .800   .906   .930  1.000
   .044   .042   .037   .029   .021  0.000
   .600   .700   .800   .900   .930  1.000
   .040   .056   .050   .037   .030  0.000

                                        MATCHED BOUNDARY LAYER BLEED

TABLE6B  NUMBER OF POINTS =      5.
  0.000   .900  1.200  1.600  2.000
  0.000  0.000   .010   .020   .030
```

Figure 26. Derivative Procedure Output File (continued)

BYPASS MASS FLOW

TABLE7 NUMBER OF Y POINTS = 6.
NUMBER OF X POINTS = 2. 2. 4. 4. 4.

0.000	1.399	1.400	1.600	1.800	2.000
0.000	1.000				
0.000	0.000				
0.000	1.000				
0.000	0.000				
.400	.854	.859	1.000		
.461	.005	0.000	0.000		
.400	.872	.882	1.000		
.483	.010	0.000	0.000		
.400	.892	.906	1.000		
.506	.014	0.000	0.000		
.400	.915	.930	1.000		
.532	.015	0.000	0.000		

INLET MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	OLD VALUE
1	ASPECT RATIO	1.0000
2	SIDEPLATE CUTBACK	.2000
3	FIRST RAMP ANGLE(DEG)	7.5000
4	DESIGN MACH NUMBER	2.0000
5	COWL LIP BLUNTNESS	.0200
6	TAKE OFF DOOR AREA	.2000
7	EXTERNAL COWL ANGLE(DEG)	17.5000
8	EXIT NOZZLE TYPE FOR BLEED	1.0000
9	EXIT NOZZLE ANGLE FOR BLEED(DEG)	15.0000
10	EXIT FLAP ASPECT RATIO FOR BLEED	2.0000
11	EXIT FLAP AREA FOR BLEED	.1000
12	EXIT NOZZLE TYPE FOR BYPASS	1.0000
13	EXIT NOZZLE ANGLE FOR BYPASS(DEG)	15.0000
14	EXIT FLAP ASPECT RATIO FOR BYPASS	2.0000
15	EXIT FLAP AREA FOR BYPASS	.2000
16	SUBSONIC DIFFUSER AREA RATIO	1.5000
17	SUBSONIC DIFFUSER TOTAL WALL ANGLE(DEG)	10.0000
18	SUBSONIC DIFFUSER LOSS COEFFICIENT	.1000

Figure 26. Derivative Procedure Output File (continued)

```
                                                NEW  INLET      MAPS

                         ATS2 INLET MAP


                                                LOCAL MACH NUMBER

TABLE1   NUMBER OF POINTS =       3.
  0.000    .200  2.100
  0.000    .200  2.100

                                                RECOVERY VS MASS FLOW

TABLE2A  NUMBER OF Y POINTS =       6.
NUMBER OF X POINTS =         7.       6.       7.       7.       8.       9.
   .550    .700    .850   1.220   1.660   2.100
   .667    .762    .857    .953   1.005   1.024   1.048
   .992    .991    .985    .969    .950    .933    .879
   .572    .667    .762    .857    .905    .924
   .990    .990    .985    .974    .945    .900
   .476    .571    .667    .762    .810    .833    .862
   .990    .990    .989    .983    .975    .962    .900
   .481    .578    .674    .771    .819    .843    .869
   .979    .970    .976    .972    .966    .954    .899
   .490    .589    .687    .786    .835    .859    .869    .874
   .972    .966    .961    .954    .951    .936    .921    .898
   .499    .599    .700    .800    .900    .930    .935    .943    .950
   .950    .945    .941    .936    .927    .917    .912    .892    .842

                                                MATCHED INLET RECOVERY

TABLE2B  NUMBER OF POINTS =       9.
  0.000    .200    .400    .600    .800   1.000   1.220   1.660   2.100
   .900    .950    .965    .972    .975    .975    .966    .944    .917

                                                MATCHED MASS FLOW

TABLE2C  NUMBER OF POINTS =       7.
   .400    .600    .800   1.000   1.220   1.660   2.100
  1.248    .922    .822    .790    .809    .857    .929

                                                BUZZ LIMIT

TABLE2D  NUMBER OF POINTS =       6.
  0.000   1.439   1.440   1.660   1.880   2.100
  0.000   0.000    .869    .869    .874    .874
```

Figure 26. Derivative Procedure Output File (continued)

```
                                          DISTORTION LIMIT

TABLE2E  NUMBER OF POINTS =      6.
   .550    .700    .800  1.220  1.660  2.100
   .337    .372    .476   .481   .490   .499

                                          SPILLAGE DRAG

TABLE3   NUMBER OF Y POINTS =      9.
NUMBER OF X POINTS =      2.      2.      7.      9.      9.      9.      7.      7.      7.
  0.000   .949   .550   .700   .850  1.220  1.440  1.660  2.100
  0.000  1.000
  0.000  0.000
  0.000  1.000
  0.000  0.300
   .286   .381   .476   .572   .667   .681  1.000
   .181   .107   .050   .014   .002  0.000  0.000
   .286   .381   .476   .572   .667   .762   .857   .905  1.000
   .304   .202   .119   .059   .030   .012   .005  0.000  0.000
   .286   .381   .476   .572   .667   .762   .857   .917  1.000
   .402   .273   .170   .094   .047   .021   .043  0.000  0.000
   .299   .386   .482   .578   .675   .771   .868   .924  1.000
   .227   .146   .084   .043   .019   .006   .001  0.000  0.000
   .292   .487   .681   .779   .884   .883  1.000
   .756   .447   .220   .118   .025  0.000  0.000
   .492   .590   .688   .786   .900   .912  1.000
   .733   .588   .388   .223   .027  0.000  0.000
   .500   .701   .801   .901   .958   .963  1.000
   .862   .499   .312   .125   .010  0.000  0.000

                                          REFERENCE SPILLAGE DRAG

TABLE3A  NUMBER OF POINTS =      3.
  0.000  1.000  2.100
  0.000  0.000  0.000

                                          REFERENCE MASS FLOW

TABLE3B  NUMBER OF POINTS =      3.
  0.000  1.000  2.100
  1.000  1.000  1.000

                                          BOUNDARY LAYER BLEED DRAG

TABLE4   NUMBER OF X-POINTS=      5.  NUMBER OF Y-POINTS=      6.
  0.000   .449   .850  1.226  1.770  2.100
  0.000   .010   .020   .041   .061
  0.000  0.000  0.000  0.000  0.000
  0.000  0.000  0.000  0.000  0.000
  0.000   .007   .014   .028   .042
  0.000   .010   .021   .042   .062
  0.000   .011   .022   .044   .066
  0.000   .012   .025   .050   .075
```

Figure 26. Derivative Procedure Output File (continued)

BYPASS DRAG

```
TABLE5    NUMBER OF X-POINTS=       7.  NUMBER OF Y-POINTS=        8.
  0.000     .849    .850   1.000   1.220   1.440   1.770   2.320
  0.000     .041    .081    .122    .162    .203    .243
  0.000    0.000   0.000   0.000   0.000   0.000   0.000
  0.000    0.000   0.000   0.000   0.000   0.000   0.000
  0.000     .082    .125    .198    .280    .380    .500
  0.000     .050    .100    .156    .217    .290    .375
  0.000     .036    .075    .117    .162    .220    .290
  0.000     .030    .082    .097    .135    .184    .240
  0.000     .325    .052    .082    .117    .160    .216
  0.000     .021    .046    .076    .113    .157    ,215
```

BOUNDARY LAYER BLEED DRAG

```
TABLE6A   NUMBER OF Y POINTS =       8.
NUMBER OF X POINTS =     2.      2.      5.      5.      5.      6.      6.      6.
  0.000     .900   1.000   1.220   1.440   1.660   1.880   2.100
  -.300     .953
  0.000    0.500
  -.000     .953
  0.000    0.000
   .574     .870    .745    .801    .957
   .008     .007    .005    .003   0.000
   .578     .674    .809    .867    .964
   .014     .013    .010    .008   0.000
   .563     .681    .836    .876    .973
   .022     .020    .015    .012   0.000
   .589     .687    .788    .883    .914    .983
   .031     .030    .027    .020    .014   0.000
   .594     .693    .793    .898    .922    .992
   .045     .043    .038    .028    .021   0.000
   .599     .700    .800    .900    .936   1.001
   .061     .057    .051    .038    .031   0.000
```

MATCHED BOUNDARY LAYER BLEED

```
TABLE6B   NUMBER OF POINTS =       5.
  0.000     .800   1.220   1.800   2.100
  0.000    0.000    .010    .020    .031
```

BYPASS MASS FLOW

```
TABLE7    NUMBER OF Y POINTS =       6.
NUMBER OF X POINTS =     2.      2.      4.      4.      4.      4.
  0.000    1.439   1.440   1.600   1.800   2.100
  0.000    1.000
  0.000    0.000
  0.000    1.000
  0.000    0.000
   .389     .831    .836   1.000
   .444     .009   0.000   0.000
   .393     .857    .867   1.000
   .475     .010   0.000   0.000
   .398     .886    .900   1.000
   .503     .014   0.000   0.000
   .402     .919    .934   1.000
   .534     .015   0.000   0.000
```

Figure 26. Derivative Procedure Output File (continued)

INLET MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	NEW VALUE
1	ASPECT RATIO	1.0000
2	SIDEPLATE CUTBACK	.2000
3	FIRST RAMP ANGLE(DEG)	7.1000
4	DESIGN MACH NUMBER	2.1000
5	COWL LIP BLUNTNESS	.0200
6	TAKE OFF DOOR AREA	.2000
7	EXTERNAL COWL ANGLE(DEG)	17.5000
8	EXIT NOZZLE TYPE FOR BLEED	1.0000
9	EXIT NOZZLE ANGLE FOR BLEED(DEG)	15.0000
10	EXIT FLAP ASPECT RATIO FOR BLEED	2.0000
11	EXIT FLAP AREA FOR BLEED	.1000
12	EXIT NOZZLE TYPE FOR BYPASS	1.0000
13	EXIT NOZZLE ANGLE FOR BYPASS(DEG)	15.0000
14	EXIT FLAP ASPECT RATIO FOR BYPASS	2.0000
15	EXIT FLAP AREA FOR BYPASS	.2000
16	SUBSONIC DIFFUSER AREA RATIO	1.7000
17	SUBSONIC DIFFUSER TOTAL WALL ANGLE(DEG)	11.0000
18	SUBSONIC DIFFUSER LOSS COEFFICIENT	.1417

Figure 26. Derivative Procedure Output File (concluded)

round, convergent-divergent nozzle installation designated by File Name CD2R. This configuration and its area distribution are shown in Figure 27. The nozzle/aftbody drag characteristics for the CD2R library configuration are presented in Figure 28. $C_{D_{AB}}$ is presented as a function of free-stream Mach number and A_{10}/A_9 for a fully-expanded nozzle ($P_9/P_0 = 1.0$). Figure 29 shows the calculated effect of making a shape change to the nozzle/aftbody.

Figure 30 presents the old (library configuration) nozzle/aftbody derivative parameters that were used as input for the twin round convergent-divergent nozzle configuration, and Figure 31 shows the new nozzle/aftbody derivative parameter data that were used as interactive user input into the derivative procedure program. The sample interactive input used to create a new nozzle/aftbody drag map using a shape change are presented in Figure 32. Figure 33 presents the output from the TAPE6 nozzle/aftbody drag calculations which shows both the old and new aftbody drag maps resulting from the interactive session.

5.3 NOZZLE C_{F_G} DERIVATIVE PROCEDURE SAMPLE CASE

The nozzle configuration used to demonstrate the nozzle C_{F_G} derivative procedure is the round convergent-divergent nozzle configuration designated as CV1. This nozzle configuration is shown in Figure 34. Also shown plotted in Figure 34 is the baseline nozzle C_{F_G} variation as a function of nozzle pressure ratio and area ratio. These plotted data are used in table form as the old nozzle input map Figure 35. Figure 36 shows the old nozzle derivative parameters for the library nozzle. Figure 37 presents the sample interactive input commands used to create a new nozzle C_{F_G} map file which corresponds to a new nozzle divergence half-angle of 12.5 degrees. The calculated results (TAPE6 output) showing both the old and new nozzle C_{F_G} maps is presented in Figure 38. Plotted data showing the effect of changing the nozzle divergence half-angle from 11.45° to 12.5° for a nozzle area ratio of 1.60 are presented in Figure 39.

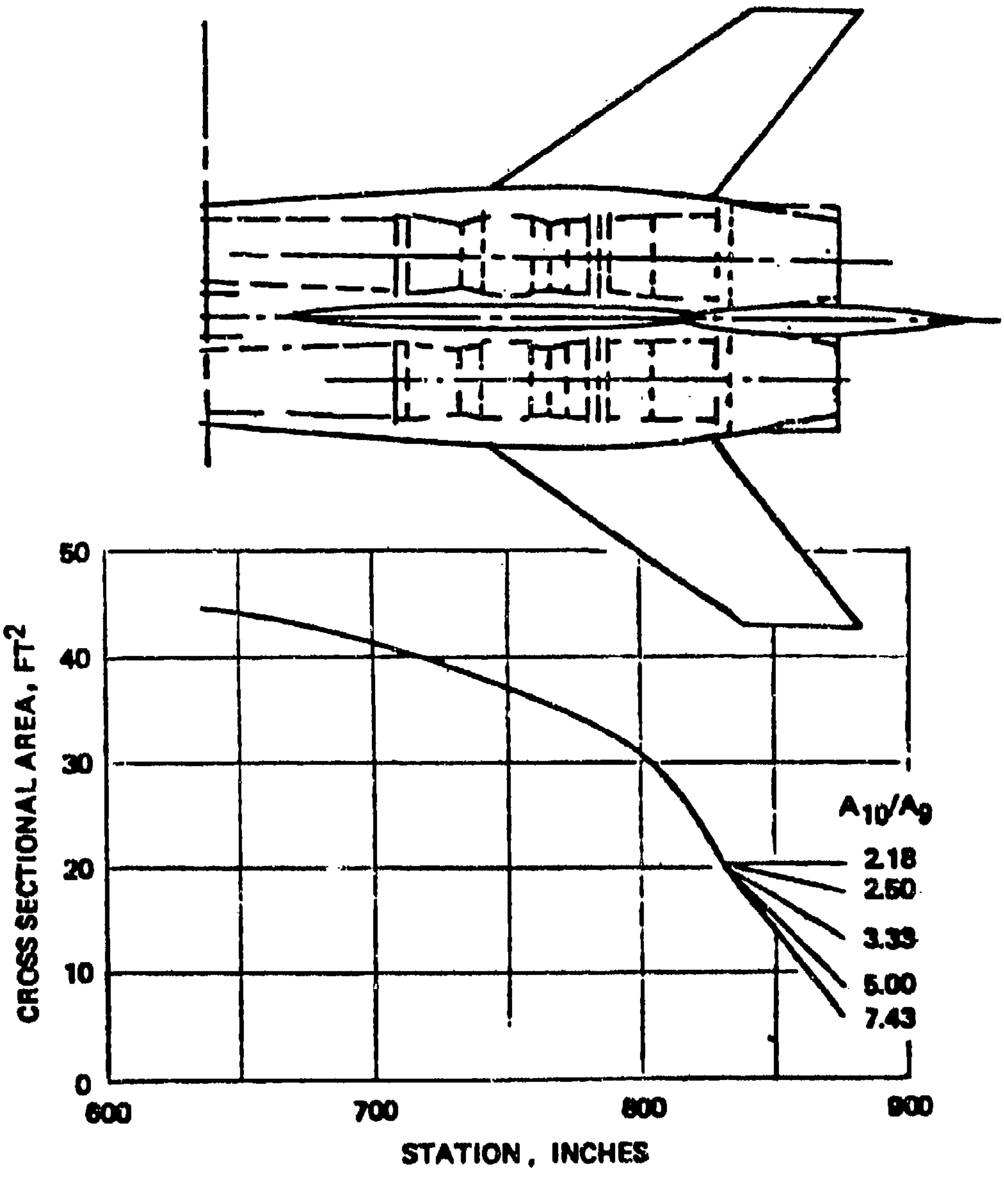


Figure 27 CD2R Nozzle/Aftbody Configuration and Area Distribution

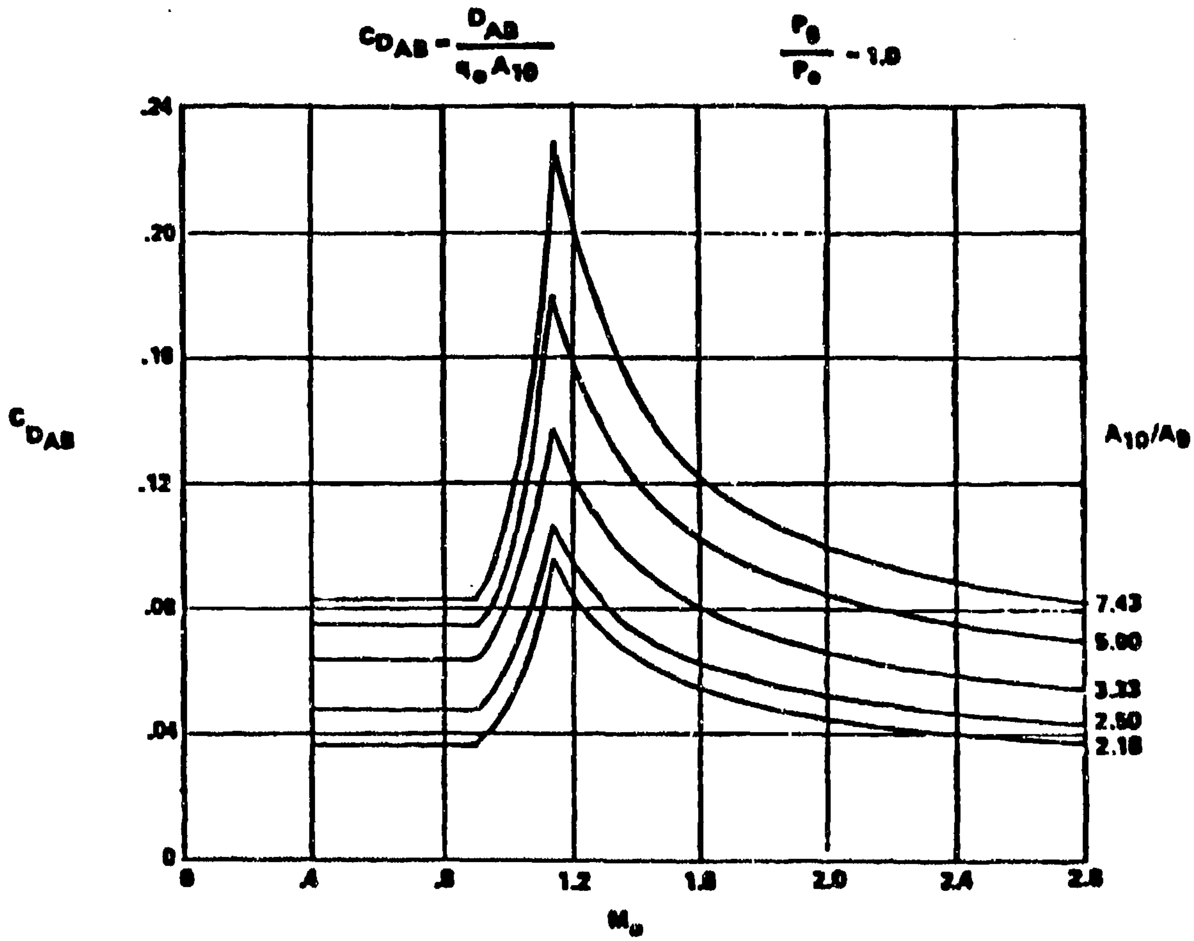
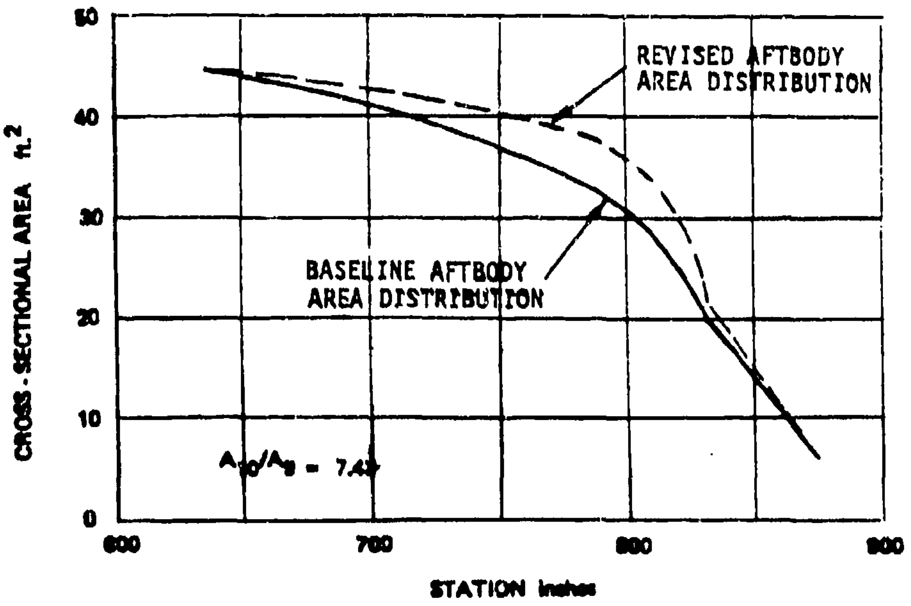


Figure 28 Nozzle/Aftbody Drag Map for Twin Round Nozzles



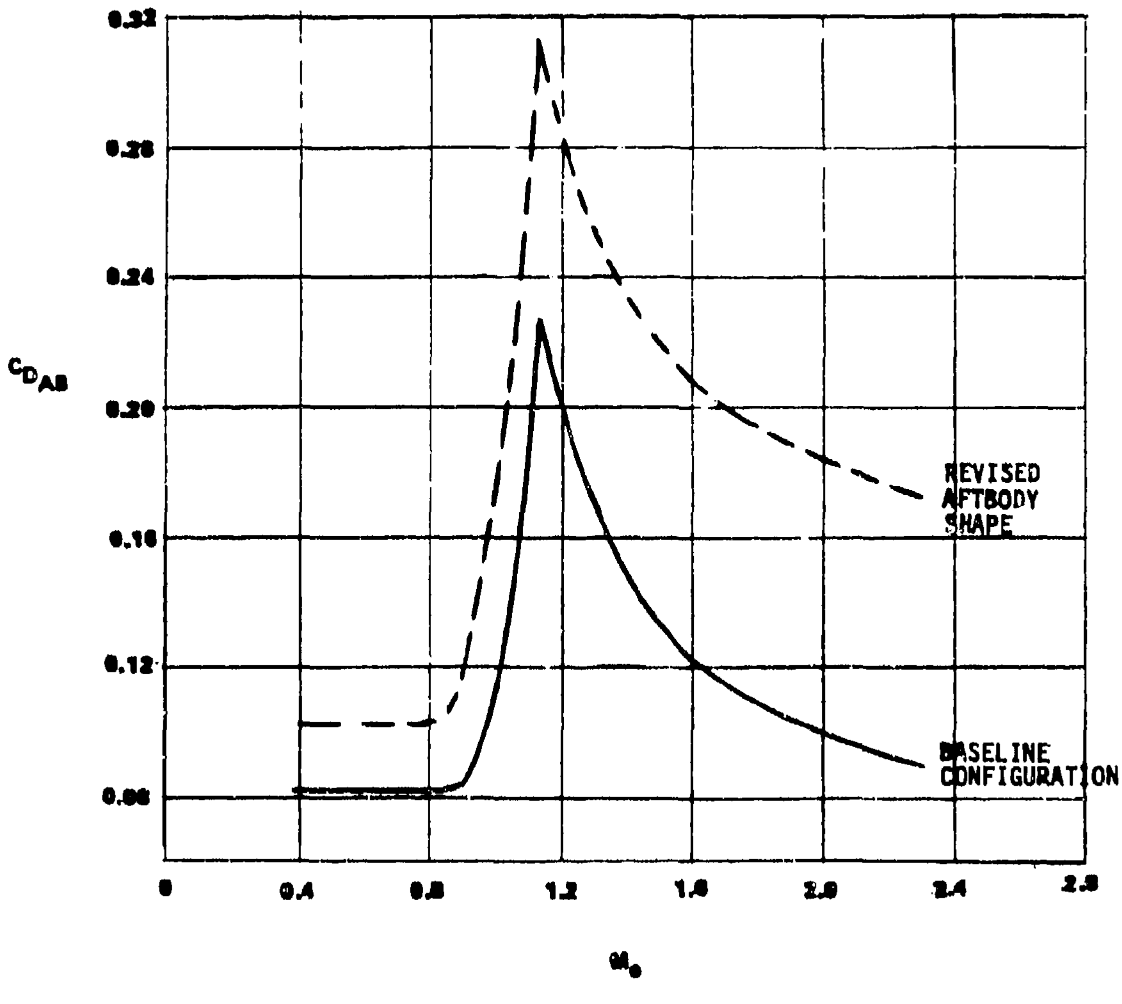


Figure 29. Comparison of New and Old Nozzle/Aftbody Drag Maps

```
                                       OLD  AFTERBODY MAPS

A                    CD2R INPUT MAP
|

                                      AFTERBODY DRAG TABLE

  TABLEAB  NUMBER OF X-POINTS=       8.  NUMBER OF Y-POINTS=       5.
    2.180   2.500   3.330   5.000   7.417
     .400    .900   1.130   1.200   1.400   1.600   2.000   2.300
     .037    .037    .096    .084    .065    .055    .045    .042
     .040    .040    .107    .095    .072    .063    .051    .048
     .064    .064    .138    .122    .094    .081    .066    .060
     .075    .075    .180    .156    .120    .103    .085    .077
     .083    .083    .220    .200    .143    .122    .100    .090

                    AFTERBODY MAP DERIVATIVE PARAMETERS
  PARAMETER NUMBER            PARAMETER DEFINITION            OLD VALUE

           1          NOZZLE STATIC PRESSURE RATIO                  1.0000
           2          TAIL FIN CONFIGURATION                        2.0000
           3          TAIL FIN ANGLE(DEG)                           0.0000
           4          TAIL FIN FORE AND AFT LOCATION RATIO           .1736
           5          BASE AREA RATIO                               0.0000

  THE FOLLOWING ARE THE TABLES OF STATION(IN) VERSUS AREA(SQFT)

            TABLE NUMBER =  1            A10/A9 =     2.18
                                  STATION AND AREA
  637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
  850.00  20.50 876.00  20.50

            TABLE NUMBER =  2            A10/A9 =     2.50
                                  STATION AND AREA
  637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
  850.00  20.50 876.00  17.84

            TABLE NUMBER =  3            A10/A9 =     3.33
                                  STATION AND AREA
  637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
  850.00  20.50 876.00  13.35

            TABLE NUMBER =  4            A10/A9 =     5.00
                                  STATION AND AREA
  637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
  850.00  20.50 876.00   8.92

            TABLE NUMBER =  5            A10/A9 =     7.42
                                  STATION AND AREA
  637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
  850.00  20.50 876.00   6.00
```

Figure 30. Old Nozzle/Aftbody Derivative Parameters

```
           TABLE NUMBER =  6              A10/A9 =    7.42
                                   STATION AND AREA
   637.00   44.50 700.00   43.00 760.00   40.00 800.00   36.00 820.00   30.00
   850.00   22.00 876.60    6.00
```

Figure 31. New Nozzle/Aftbody Derivative Parameters

```
          DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1   FOR INLET MAP CHANGES
 2   FOR NOZZLE/AFTBODY CHANGES
 3   FOR CV MAP CHANGES

I>2

CD2R INPUT MAP


 ENTER CODE FOR OUTPUT DESIRED
 0  FOR TAPE6 OUTPUT ONLY
 1  FOR TAPE6 OUTPUT AND TAPE1(NEW PIPSI) FILE

I>1

 AFTERBODY TYPE = CD-AXISYMMETRIC DUAL NOZZLE
                   AFTERBODY MAP DERIVATIVE PARAMETERS
 PARAMETER NUMBER           PARAMETER DEFINITION                 OLD VALUE
       1          NOZZLE STATIC PRESSURE RATIO                    1.0000
       2          TAIL FIN CONFIGURATION                          2.0000
       3          TAIL FIN ANGLE(DEG)                             0.0000
       4          TAIL FIN FORE AND AFT LOCATION RATIO             .1736
       5          BASE AREA RATIO                                 0.0000

 INPUT NUMBER OF PARAMETERS TO BE CHANGED

I>0

 ARE DERIVATIVE PARAMETERS CORRECT(0=YES  1=NO)

I>0

 THE FOLLOWING ARE THE OLD TABLES(STATION(IN) VERSUS AREA(SQFT))
 ASSOCIATED WITH A PARTICULAR A10/A9
 THE USER MAY CHANGE A TABLE VALUE FOR A
 PARTICULAR A10/A9 RATIO


         TABLE NUMBER =  1   A10/A9 =    2.18
                           STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00  20.50

         TABLE NUMBER =  2   A10/A9 =    2.50
                           STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00  17.84
```

Figure 32. Sample Interactive Input for Creating a New Nozzle/Aftbody Drag Map

```
          TABLE NUMBER =  3    A10/A9 =     3.33
                             STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00  13.39

          TABLE NUMBER =  4    A10/A9 =     5.00
                             STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00   8.92

          TABLE NUMBER =  5    A10/A9 =     7.43
                             STATION AND AREA
 637.00  44.50 700.00  41.50 760.00  36.00 800.00  31.00 820.00  25.00
 830.00  20.50 876.00   6.00

 DO YOU WISH TO CHANGE A TABLE (0=NO 1=YES)

I>1

 ENTER THE TOTAL NUMBER OF TABLES TO BE CHANGED
I>1

 ENTER THE CORRESPONDING  NUMBERS OF THE TABLES TO BE CHANGED

I>5

 HOW MANY POINTS ARE IN YOUR NEW TABLE          5

I>7

 INPUT THE POINTS IN PAIRS(STATION(IN),AREA(SQFT))

I>637. 44.5 700. 43. 760. 40. 800. 36. 820. 30. 830. 22. 876. 6.

 THE FOLLOWING ARE THE NEW TABLES(STATION(IN) VERSUS AREA(SQFT))
 ASSOCIATED WITH A PARTICULAR A10/A9
 THE USER MAY CHANGE A TABLE VALUE FOR A
 PARTICULAR A10/A9 RATIO


          TABLE NUMBER =  5    A10/A9 =     7.42
                             STATION AND AREA
 637.00  44.50 700.00  43.00 760.00  40.00 800.00  36.00 820.00  30.00
 830.00  22.00 876.00   6.00

 ARE TABLES CORRECT(0=YES  1=NO)
I>0
 DO YOU WISH TO CHANGE THE DEFAULT A9A8 SCHEDULE(0=NO  1=YES)

I>0
         DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1   FOR INLET MAP CHANGES
 2   FOR NOZZLE/AFTBODY CHANGES
 3   FOR CV MAP CHANGES

I>"END"
```

Figure 32. Sample Interactive Input for Creating a New Nozzle/Aftbody Drag Map (concluded)

OLD AFTERBODY MAPS

~~CD20 INPUT MAP~~

AFTERBODY DRAG TABLE

TABLEAB NUMBER OF X-POINTS= 8. NUMBER OF Y-POINTS= 5.

~~2.150~~	~~2.500~~	~~3.330~~	~~5.000~~	~~7.417~~			
.400	.900	1.130	1.200	1.400	1.600	2.000	2.300
.037	.037	.096	.084	.065	.055	.045	.042
~~.048~~	~~.048~~	~~.107~~	~~.095~~	~~.072~~	~~.063~~	~~.053~~	~~.048~~
.064	.064	.138	.122	.094	.081	.066	.060
.075	.075	.160	.156	.120	.103	.085	.077
~~.083~~	~~.083~~	~~.220~~	~~.200~~	~~.143~~	~~.122~~	~~.100~~	~~.090~~

~~AFTERBODY MAP DERIVATIVE PARAMETERS~~

PARAMETER NUMBER	PARAMETER DEFINITION	OLD VALUE
~~1~~	~~NOZZLE STATIC PRESSURE RATIO~~	~~1.0000~~
2	TAIL FIN CONFIGURATION	2.0000
3	TAIL FIN ANGLE(DEG)	0.0000
~~4~~	~~TAIL FIN FORE AND AFT LOCATION RATIO~~	~~.1736~~
5	BASE AREA RATIO	0.0000

THE FOLLOWING ARE THE TABLES OF STATION(IN) VERSUS AREA(SQFT)

TABLE NUMBER = 1 A10/A9 = 2.18

~~STATION AND AREA~~

637.00 44.50 700.00 41.50 760.00 36.00 800.00 31.00 820.00 25.00
830.00 20.50 876.00 20.50

TABLE NUMBER = 2 A10/A9 = 2.50

STATION AND AREA

~~637.00 44.50 700.00 41.50 760.00 36.00 800.00 31.00 820.00 25.00~~
830.00 20.50 876.00 17.84

~~TABLE NUMBER = 3 A10/A9 = 3.33~~

STATION AND AREA

637.00 44.50 700.00 41.50 760.00 36.00 800.00 31.00 820.00 25.00
~~830.00 20.50 876.00 13.39~~

TABLE NUMBER = 4 A10/A9 = 5.00

~~STATION AND AREA~~

637.00 44.50 700.00 41.50 760.00 36.00 800.00 31.00 820.00 25.00
830.00 20.50 876.00 8.92

TABLE NUMBER = 5 A10/A9 = 7.42

STATION AND AREA

~~637.00 44.50 700.00 41.50 760.00 36.00 800.00 31.00 820.00 25.00~~
830.00 20.50 876.00 6.00

Figure 33. Output from Nozzle/Aftbody Drag Map Calculation

NEW AFTERBODY MAPS

USER INPUT MAP

AFTERBODY DRAG TABLE

TABLEAB NUMBER OF X-POINTS= 8. NUMBER OF Y-POINTS= 5.

2.180	2.500	3.333	5.000	7.417			
.400	.500	1.130	1.200	1.400	1.600	2.000	2.300
.037	.037	.096	.084	.065	.058	.045	.042
.048	.048	.167	.095	.072	.063	.053	.048
.064	.064	.138	.122	.094	.081	.066	.060
.075	.075	.180	.158	.120	.103	.085	.077
.105	.127	.314	.266	.234	.298	.108	.176

AFTERBODY DRAG CORRECTION

TABLEAD NUMBER OF X POINTS = 5. NUMBER OF Y POINTS = 5.

NUMBER OF Z POINTS = 4.

2.180	3.926	5.671	7.417	
.400	.875	1.350	1.825	2.300
.500	1.000	1.500	2.000	3.000
.105	0.000	-.105	-.210	-.420
.114	0.000	-.114	-.227	-.455
.068	0.000	-.068	-.137	-.274
.015	-.000	-.015	-.030	-.061
.002	0.000	-.002	-.004	-.009
.036	0.000	-.036	-.072	-.143
.039	0.000	-.039	-.077	-.155
.023	0.000	-.023	-.047	-.093
.005	0.000	-.005	-.010	-.021
.001	0.000	-.001	-.001	-.003
.024	0.000	-.024	-.048	-.096
.026	0.000	-.026	-.052	-.104
.016	0.000	-.016	-.031	-.063
.003	-.000	-.003	-.007	-.014
.000	0.000	-.000	-.001	-.002
.024	-.000	-.024	-.048	-.095
.026	0.000	-.026	-.051	-.103
.015	0.000	-.015	-.031	-.062
.003	0.000	-.003	-.007	-.014
.000	-.000	-.000	-.001	-.002

AFTERBODY MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	NEW VALUE
1	NOZZLE STATIC PRESSURE RATIO	1.0000
2	TAIL FIN CONFIGURATION	2.0000
3	TAIL FIN ANGLE(DEG)	5.0000
4	TAIL FIN FORE AND AFT LOCATION RATIO	.1736
5	BASE AREA RATIO	0.0000

THE FOLLOWING ARE THE TABLES OF STATION(IN) VERSUS AREA(SQFT)

Figure 33. Output from Nozzle/Afterbody Drag Map Calculation (continued)

```
            TABLE NUMBER =  1             A10/A9 =     2.18
                                 STATION AND AREA
637.00   44.50 700.00   41.50 760.00   36.00 800.00   31.00 820.00   25.00
830.00   20.50 876.00   20.50

            TABLE NUMBER =  2             A10/A9 =     2.50
                                 STATION AND AREA
637.00   44.50 700.00   41.50 760.00   36.00 800.00   31.00 820.00   25.00
830.00   20.50 876.00   17.84

            TABLE NUMBER =  3             A10/A9 =     3.33
                                 STATION AND AREA
637.00   44.50 700.00   41.50 760.00   36.00 800.00   31.00 820.00   25.00
830.00   20.50 876.00   13.39

            TABLE NUMBER =  4             A10/A9 =     5.00
                                 STATION AND AREA
637.00   44.50 700.00   41.50 760.00   36.00 800.00   31.00 820.00   25.00
830.00   20.50 876.00    8.92

            TABLE NUMBER =  5             A10/A9 =     7.40
                                 STATION AND AREA
637.00   44.50 700.00   43.00 760.00   40.00 800.00   36.00 820.00   30.00
830.00   22.50 876.00    6.03
```

Figure 33. Output from Nozzle/Aftbody Drag Map Calculation (concluded)

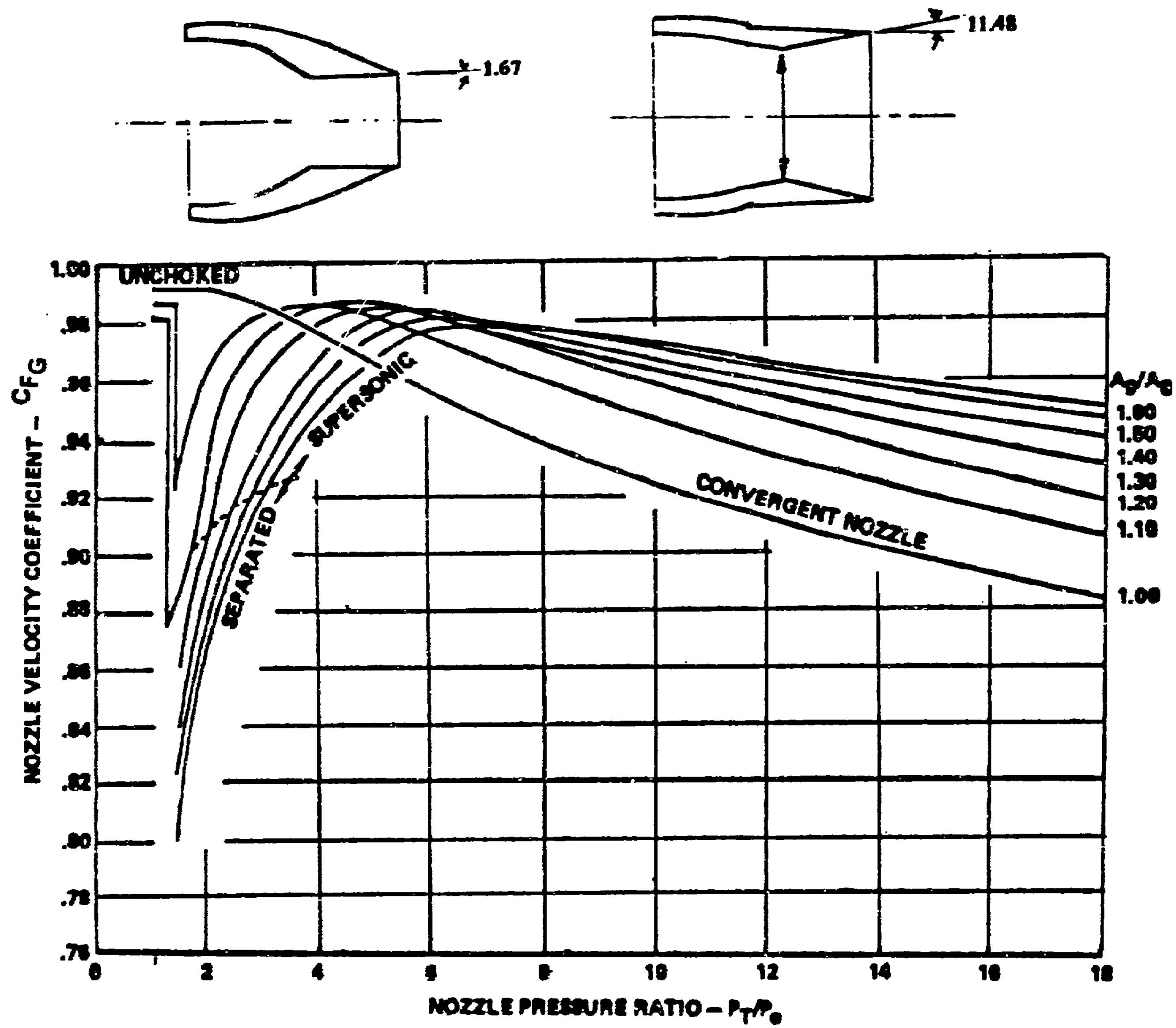


Figure 34. Gross Thrust Coefficient for a Round C-D Nozzle

OLD CFG MAPS

CV1 INPUT MAP

CFG TABLE

TABLECV NUMBER OF X-POINTS= 10. NUMBER OF Y-POINTS= 7.

1.000	1.100	1.200	1.300	1.400	1.500	1.600			
1.500	2.000	3.000	4.000	5.000	6.000	8.000	10.000	14.000	18.000
.992	.992	.986	.976	.966	.955	.936	.924	.903	.886
.832	.865	.884	.886	[illegible]	.875	.960	.947	.925	.906
.888	.935	.977	.986	.988	.983	.970	.958	.938	.920
.862	.905	.965	.982	.986	.982	.972	.964	.947	.932
.840	.890	.943	.970	[illegible]	.986	.976	.968	.954	.942
.822	.876	.932	.962	.977	.982	.978	.970	.959	.946
.800	.867	.922	.952	.970	.979	.978	.972	.961	.952

CFG MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	OLD VALUE
1	DIVERGENCE HALF ANGLE(DEG)	11.4500

Figure 35. Old Nozzle C_{F_G} Input Map

```
NOZZLE TYPE = ROUND CONVERGENT-DIVERGENT NOZZLE
                  CFG MAP DERIVATIVE PARAMETERS
PARAMETER NUMBER            PARAMETER DEFINITION            OLD VALUE
      1            DIVERGENCE HALF ANGLE(DEG)               11.4500
```

Figure 36. Old Nozzle Derivative Parameters

```
          DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1    FOR INLET MAP CHANGES
 2    FOR NOZZLE/AFTBODY CHANGES
 3    FOR CV MAP CHANGES

I>3

CV1 INPUT MAP


 ENTER CODE FOR OUTPUT DESIRED
 0  FOR TAPE6 OUTPUT ONLY
 1  FOR TAPE6 OUTPUT AND TAPE1(NEW PIPSI) FILE

I>1

 NOZZLE TYPE = ROUND CONVERGENT--DIVERGENT NOZZLE
                       CFG MAP DERIVATIVE PARAMETERS
 PARAMETER NUMBER                PARAMETER DEFINITION                      OLD VALUE
        1             DIVERGENCE HALF ANGLE(DEG)                           11.4500

 INPUT NUMBER OF PARAMETERS TO BE CHANGED

I>1

 INPUT THE PARAMETERS TO BE CHANGED FOLLOWED
 BY THE NEW VALUE IN PAIRS(PARAMETER NUMBER,NEW VALUE)

I>1 12.5
 PARAMETER NUMBER                PARAMETER DEFINITION                      NEW VALUE
        1             DIVERGENCE HALF ANGLE(DEG)                           12.5000

 ARE THE DERIVATIVE PARAMETERS CORRECT(0=YES  1=NO)

I>0
          DERIVATIVE PROCEDURE PROGRAM

 ENTER CODE FOR MAPS TO BE CHANGED
 1    FOR INLET MAP CHANGES
 2    FOR NOZZLE/AFTBODY CHANGES
 3    FOR CV MAP CHANGES

I>"END"
```

Figure 37. Sample Interactive Input for Creating a New Nozzle C_{F_G} Map

OLD CFG MAPS

CV1 INPUT MAP

CFG TABLE

TABLECV NUMBER OF X-POINTS= 10. NUMBER OF Y-POINTS= 7.

1.000 1.100 1.200 1.300 1.400 1.500 1.603

1.500	2.000	3.000	4.000	5.000	6.000	8.000	10.000	14.000	18.000
.992	.992	.986	.976	.966	.955	.936	.924	.903	.886
.931	.965	.984	.986	.983	.975	.960	.947	.925	.900
.888	.935	.977	.986	.988	.983	.978	.958	.938	.920
.862	.905	.965	.982	.986	.982	.972	.964	.947	.932
.848	.890	.943	.974	.983	.986	.976	.968	.954	.942
.822	.876	.932	.962	.977	.982	.978	.970	.959	.946
.800	.867	.922	.952	.970	.979	.978	.972	.961	.952

CFG MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	OLD VALUE
1	DIVERGENCE HALF ANGLE(DEG)	11.4580

NEW CFG MAPS

CV1 INPUT MAP

CFG TABLE

TABLECV NUMBER OF X-POINTS= 10. NUMBER OF Y-POINTS= 7.

1.000 1.100 1.200 1.300 1.400 1.500 1.603

1.500	2.000	3.000	4.000	5.000	6.000	8.000	10.000	14.000	18.000
.992	.992	.986	.976	.966	.955	.938	.924	.903	.886
.930	.965	.984	.986	.983	.975	.960	.947	.925	.900
.887	.934	.976	.985	.987	.982	.969	.957	.937	.919
.861	.904	.964	.981	.985	.981	.971	.963	.946	.931
.848	.838	.942	.968	.981	.984	.974	.966	.952	.940
.820	.874	.930	.960	.975	.980	.976	.968	.957	.946
.797	.864	.919	.949	.967	.976	.978	.969	.958	.949

CFG MAP DERIVATIVE PARAMETERS

PARAMETER NUMBER	PARAMETER DEFINITION	NEW VALUE
1	DIVERGENCE HALF ANGLE(DEG)	12.5000

Figure 38. Terminal Output for Nozzle C_{F_G} Map

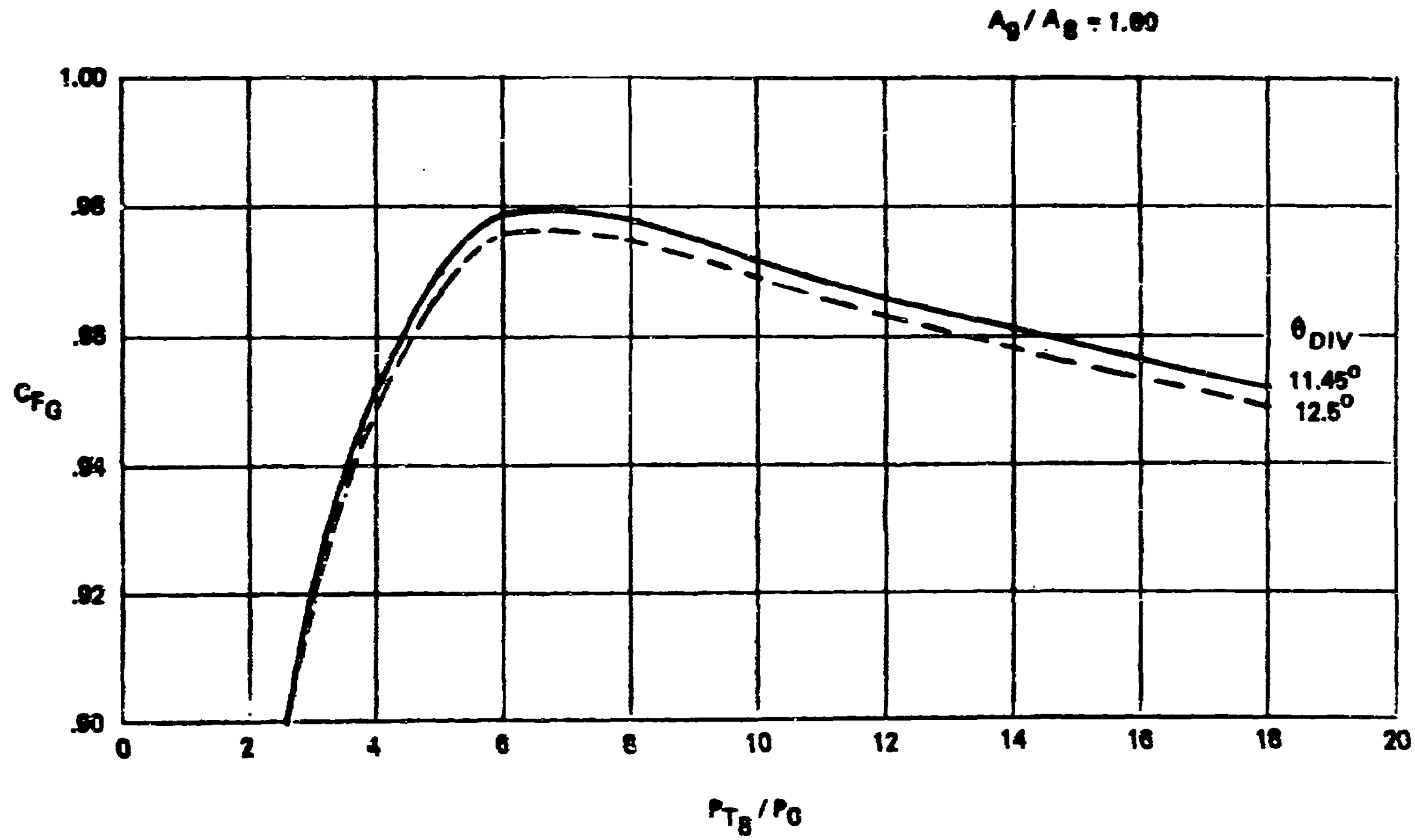


Figure 39. Effect of Change in Divergence Half-Angle on C_{F_G} of a Round C-D Nozzle

SECTION VI
FLOW CHARTS

This section presents the engineering flow charts used to develop the derivative procedure computer program. Section 6.1 presents the inlet derivative procedure flow charts, Section 6.2 presents the nozzle/aftbody drag derivative procedure flow charts, and Section 6.3 presents the nozzle gross thrust coefficient derivative procedure flow charts.

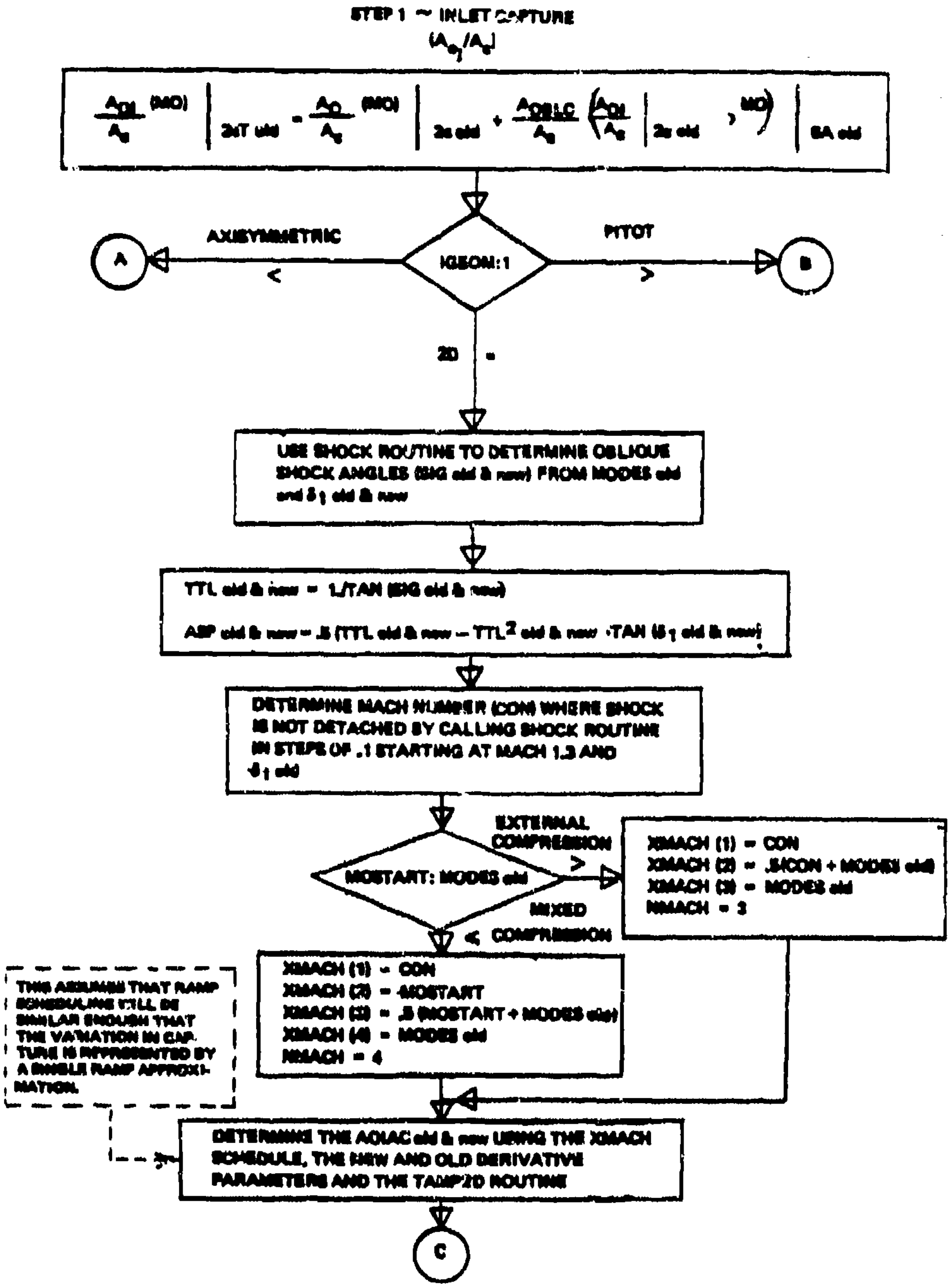


Figure 40. Flow Chart for Step 1

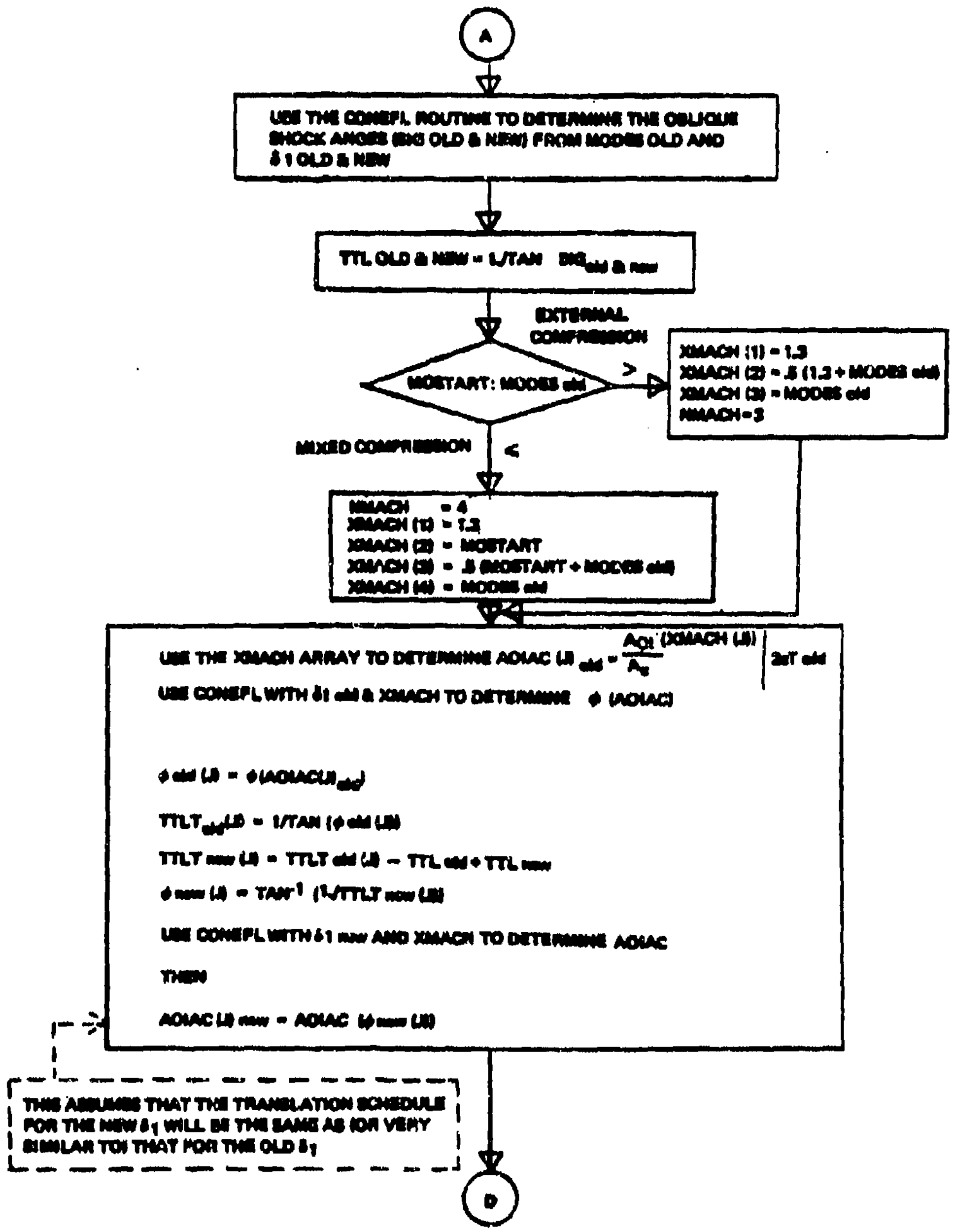


Figure 40. Flow Chart for Step 1 (cont'd)

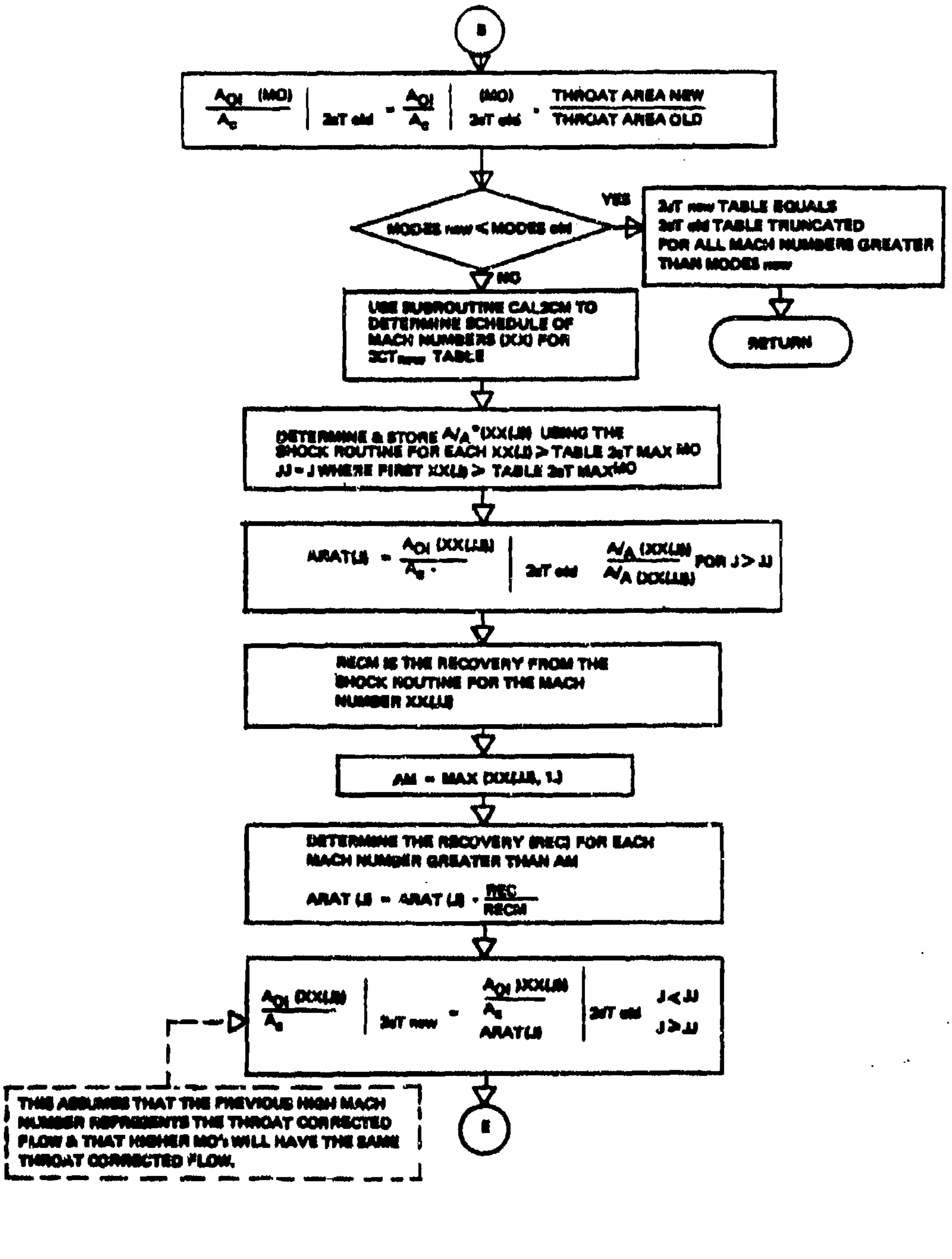


Figure 40. Flow Chart for Step 1 (cont'd)

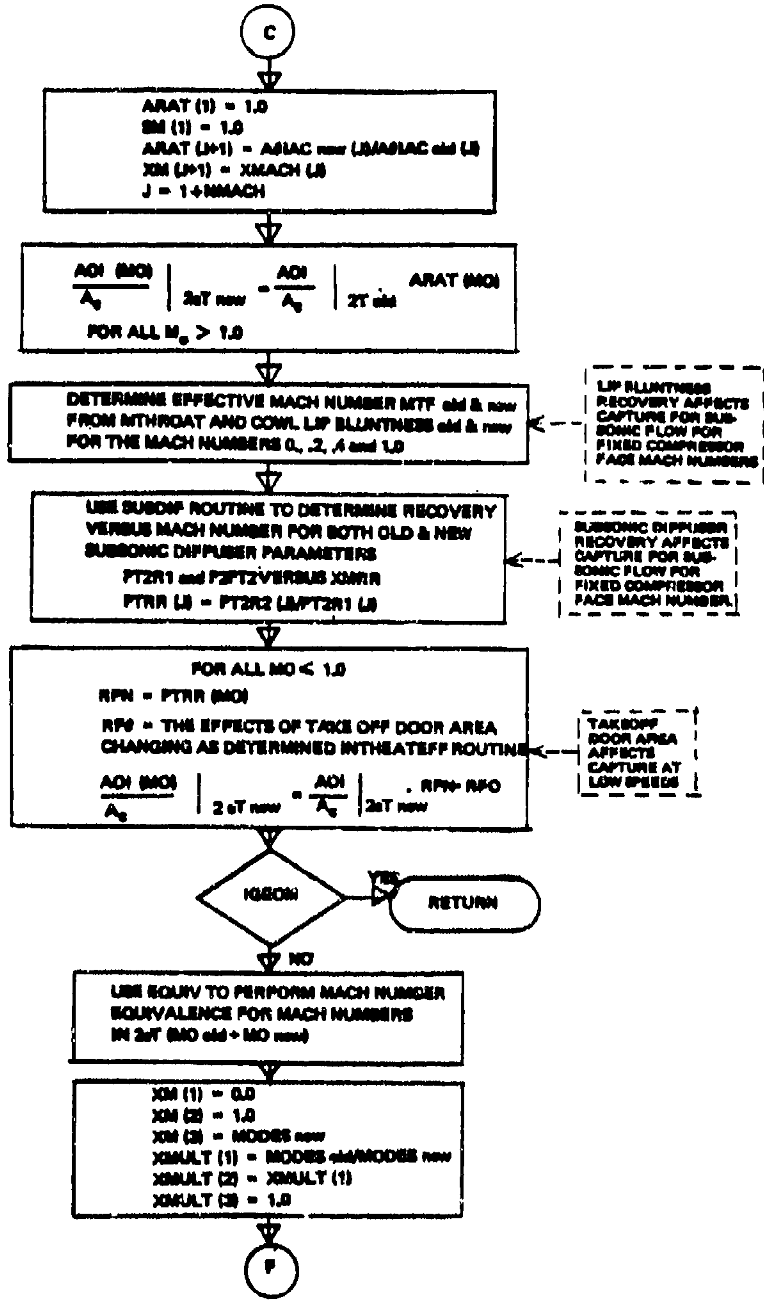


Figure 40. Flow Chart for Step 1 (cont'd)

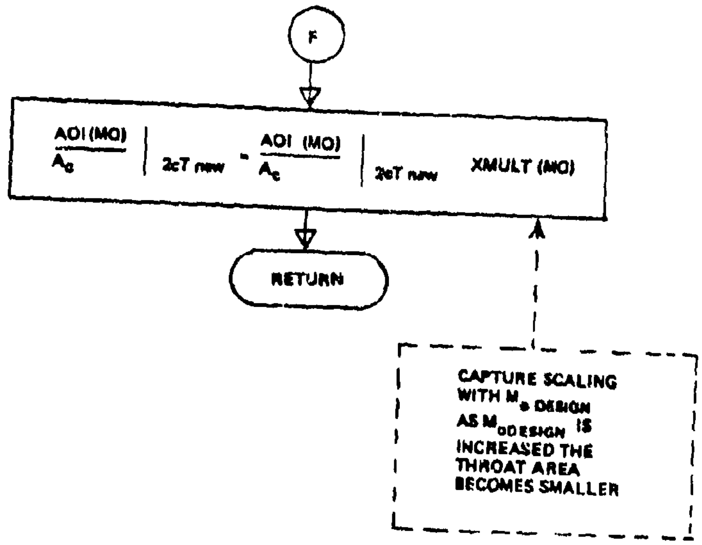


Figure 40, Flow Chart for Step 1 (concluded)

STEP 2. BOUNDARY LAYER CONTROL MASS FLOW RATIO ($A_{0\,BLC}/A_c$)

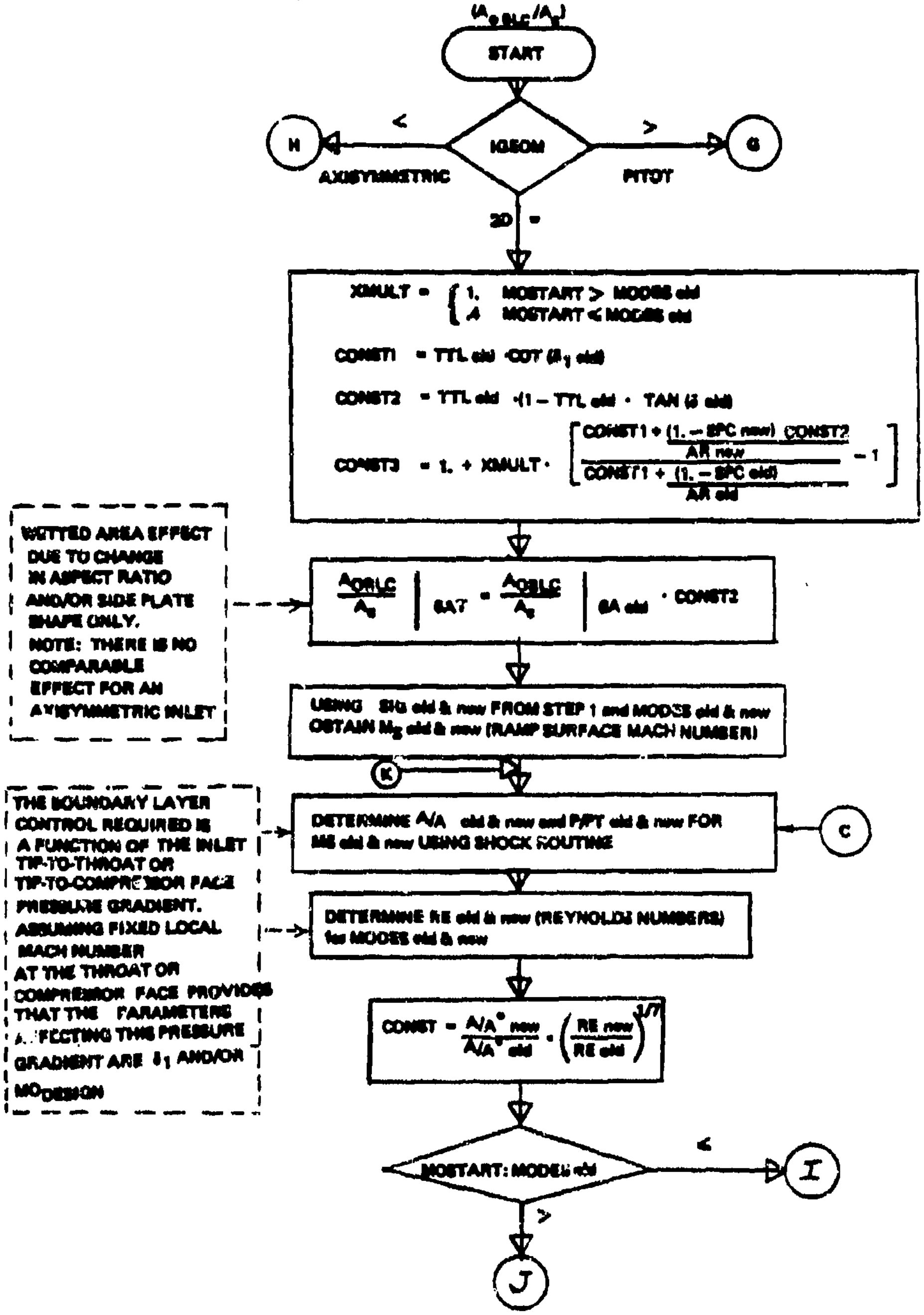


Figure 41. Flow Chart for Step 2

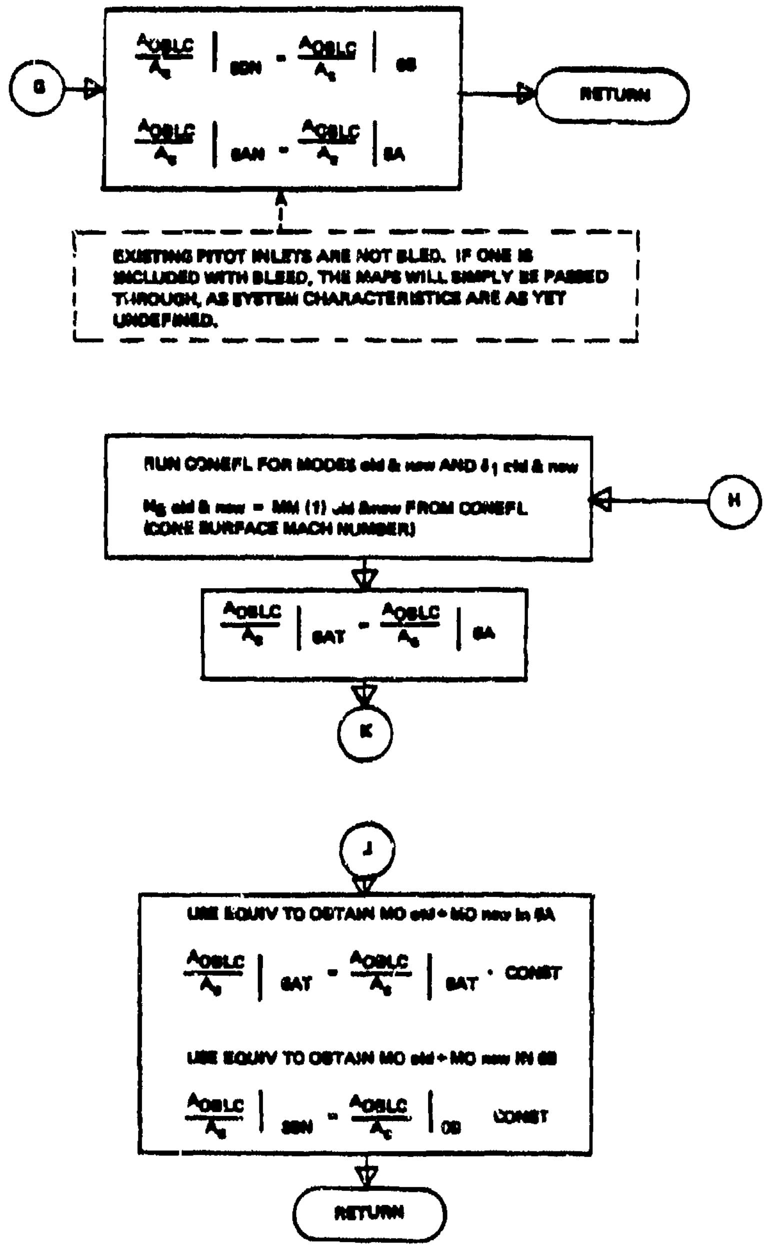


Figure 41. Flow Chart for Step 2 (cont'd)

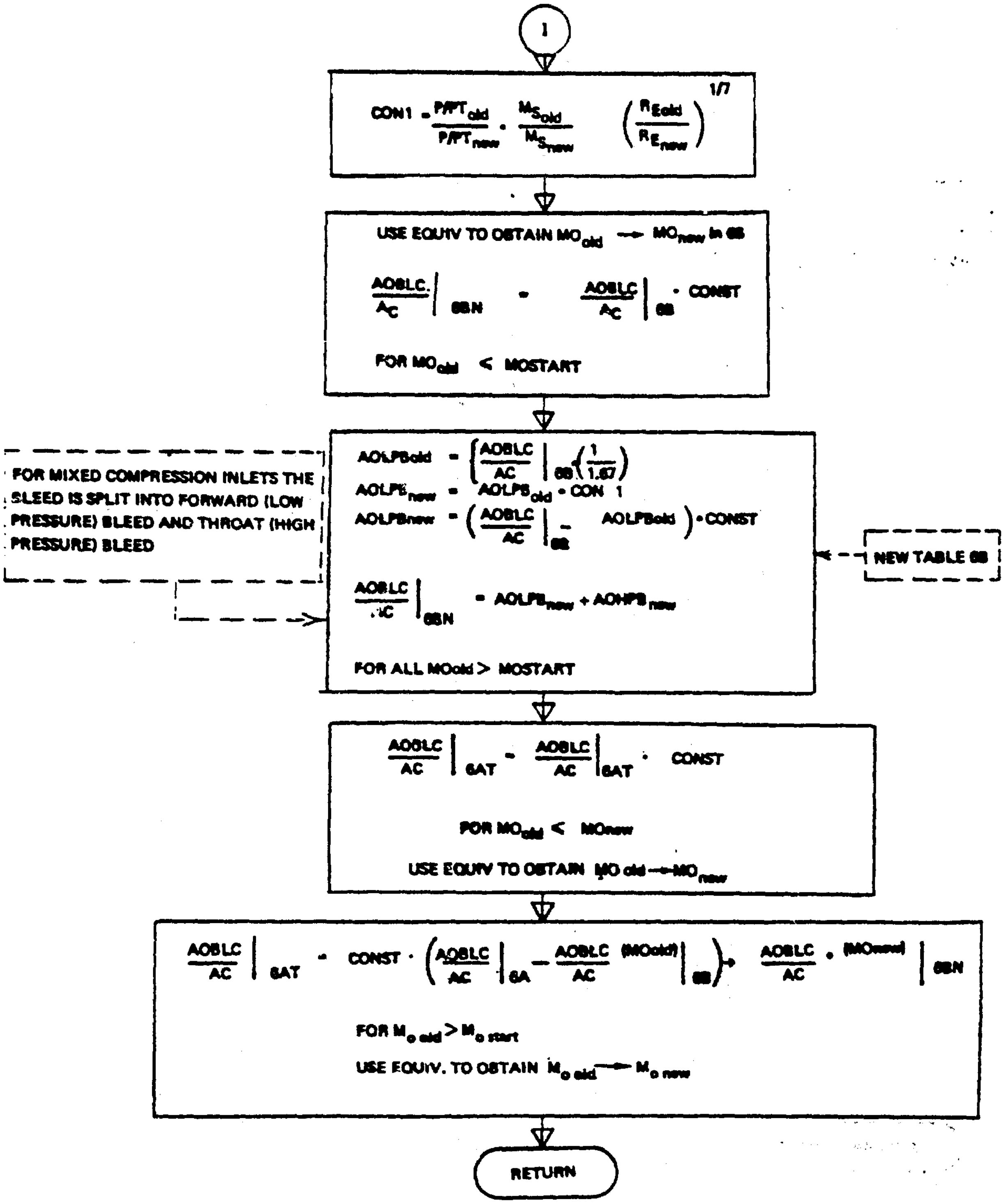


Figure 41. Flow Chart for Step 2 (concluded)

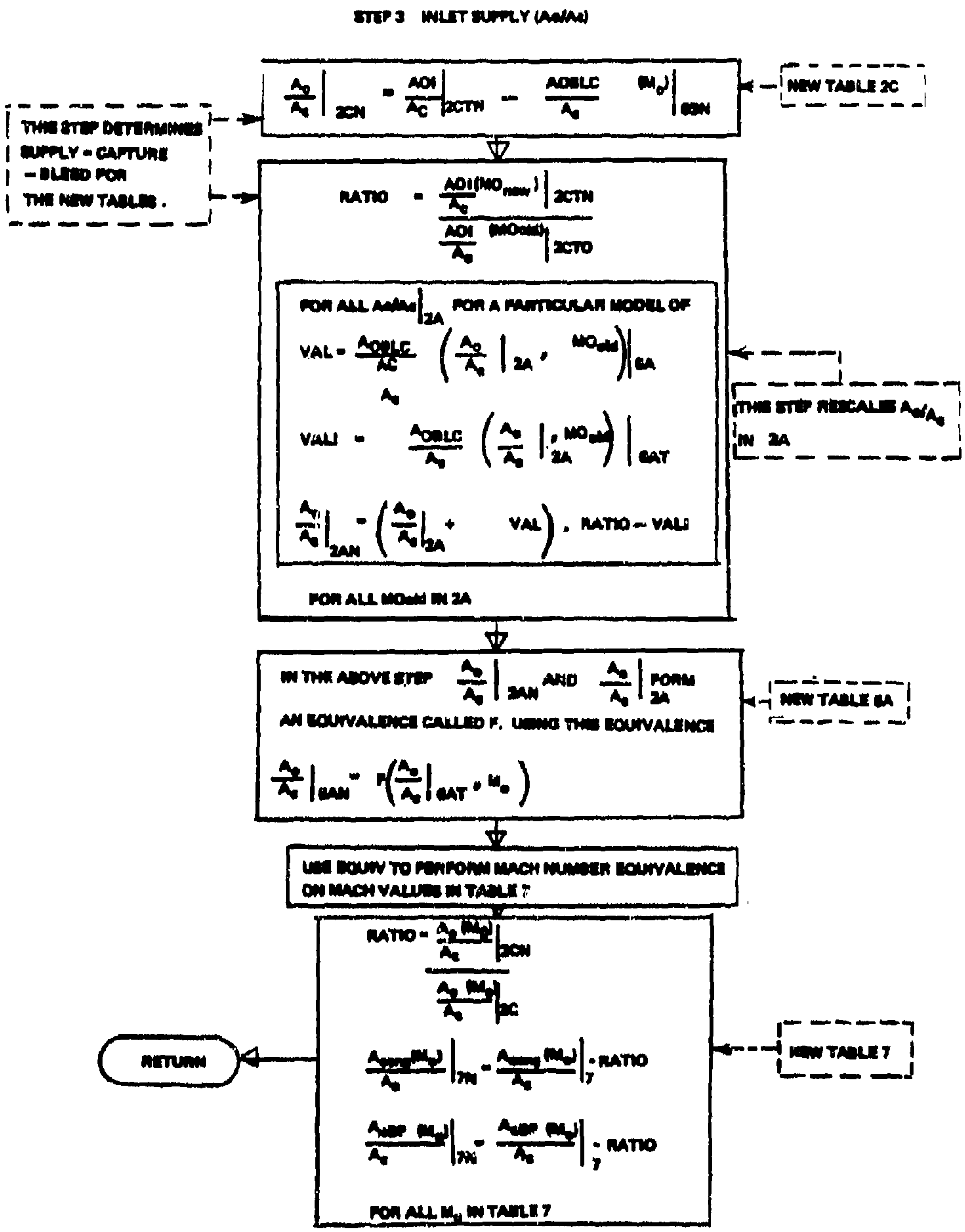


Figure 42. Flow Chart for Step 3

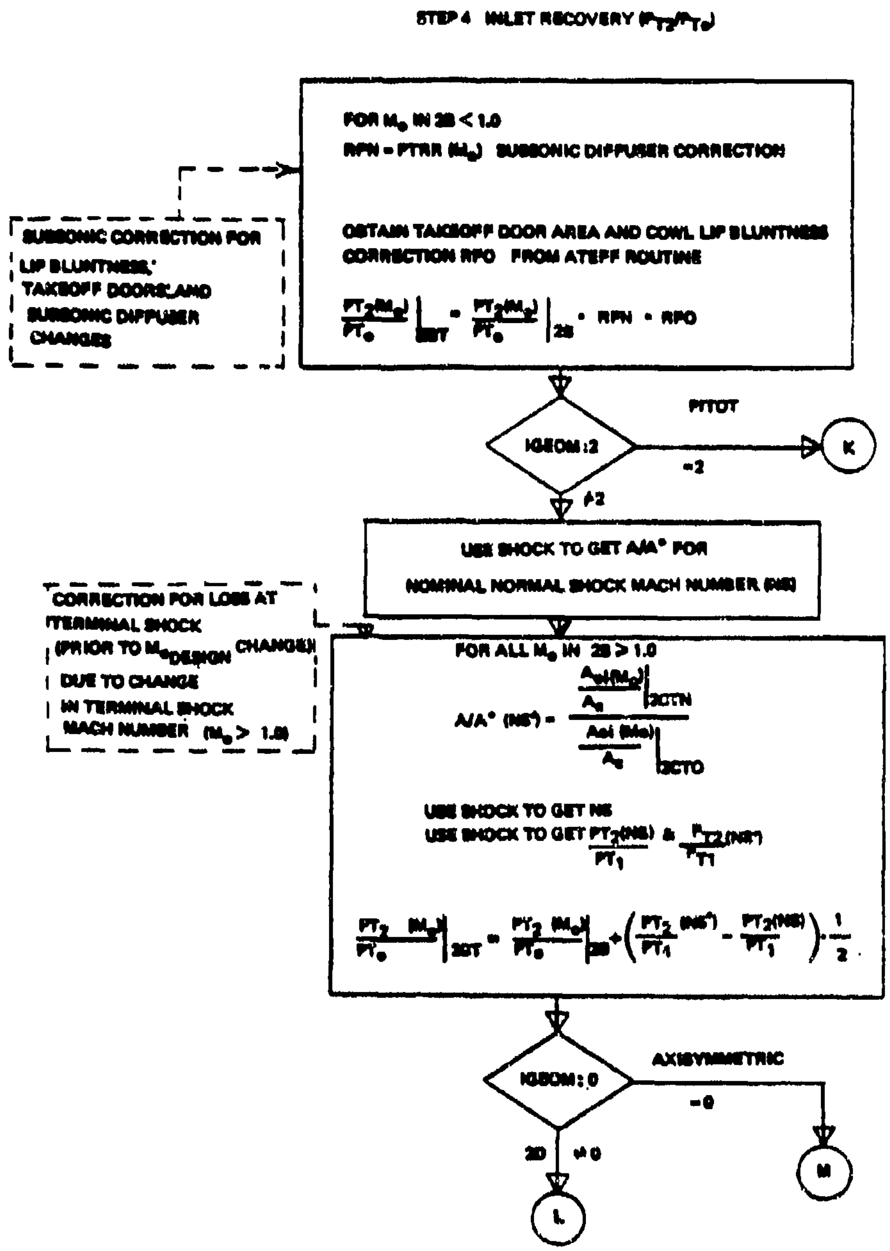


Figure 43. Flow Chart for Step 4

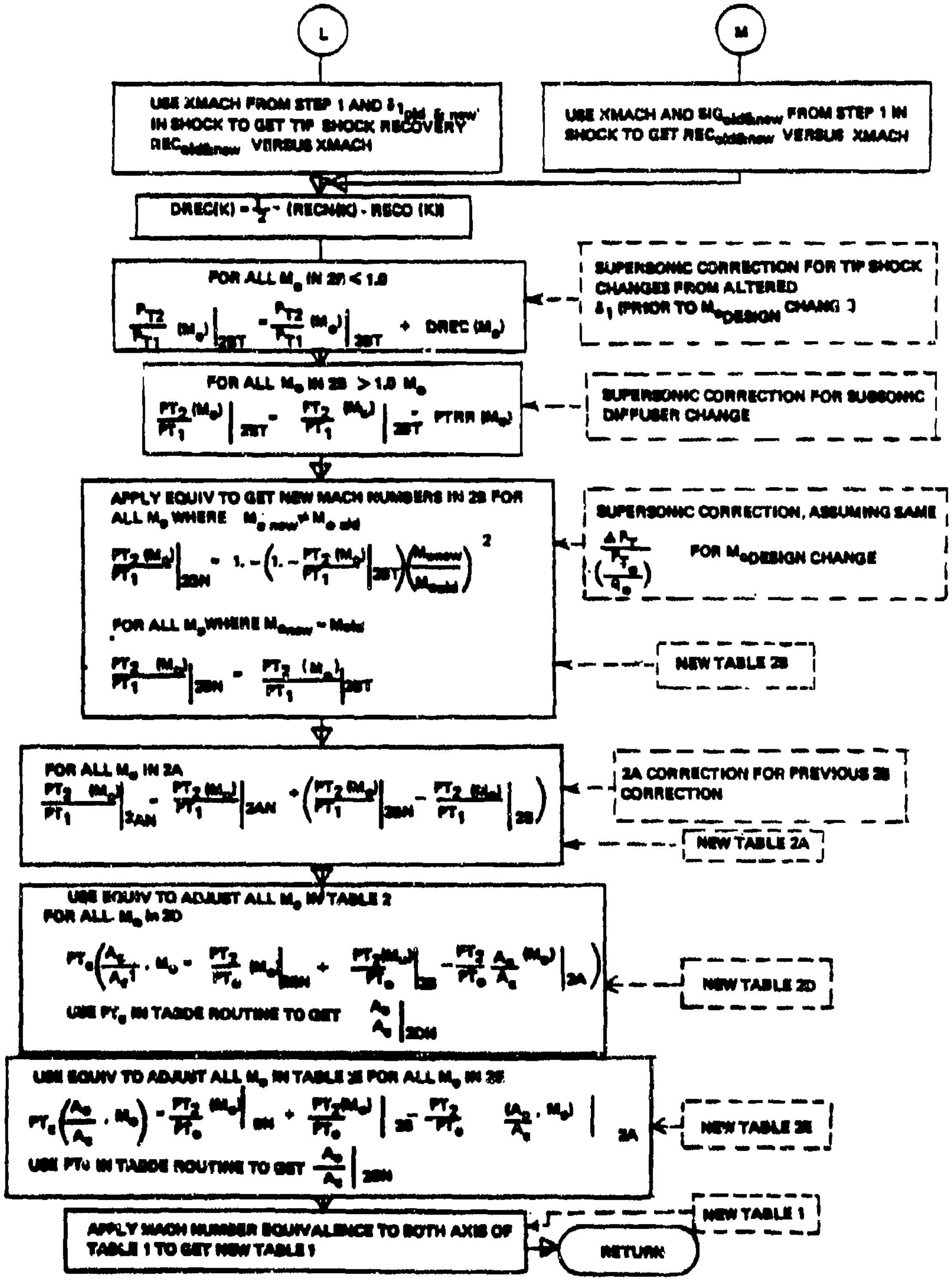


Figure 43. Flow Chart for Step 4 (concluded)

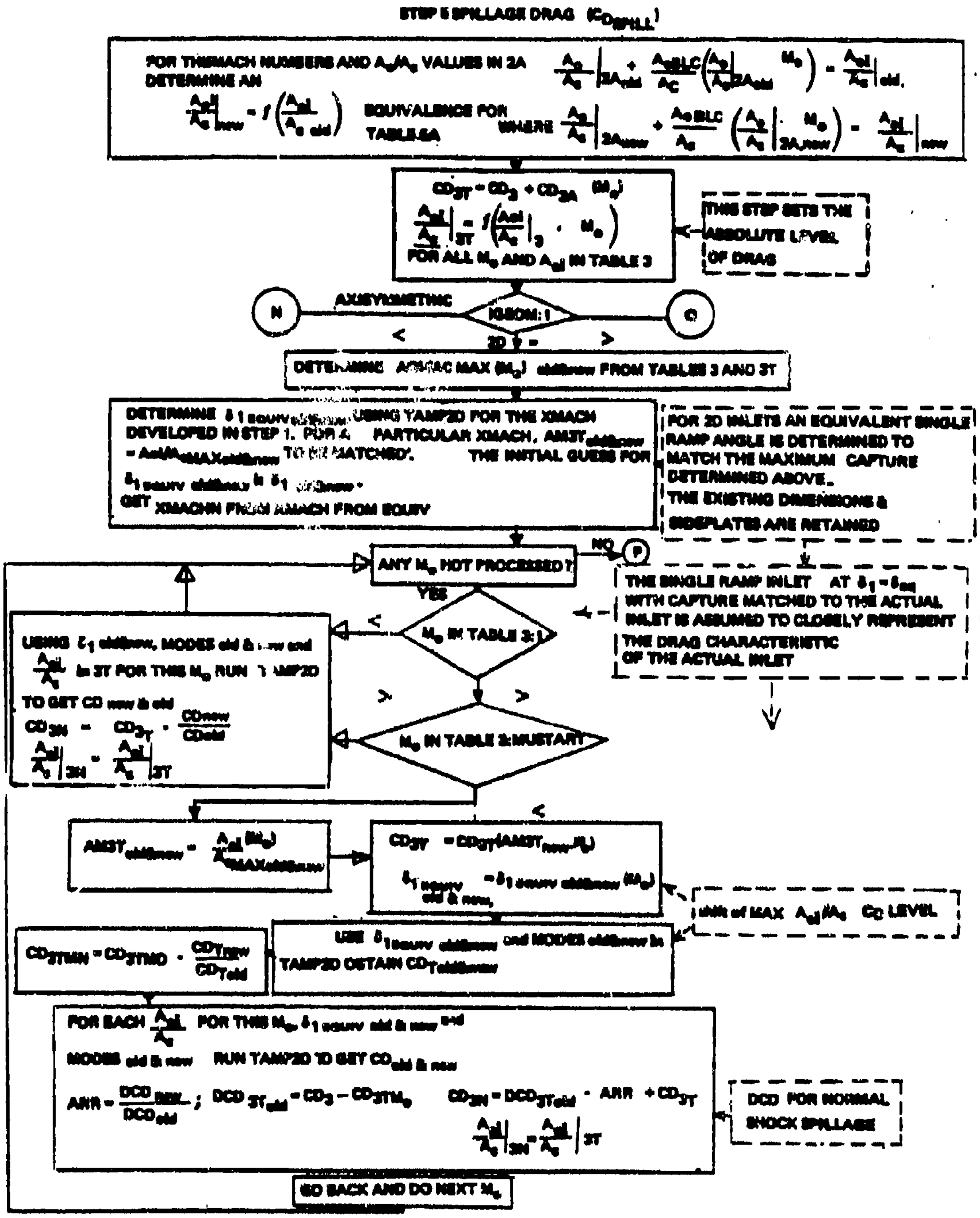


Figure 44. Flow Chart for Step 5

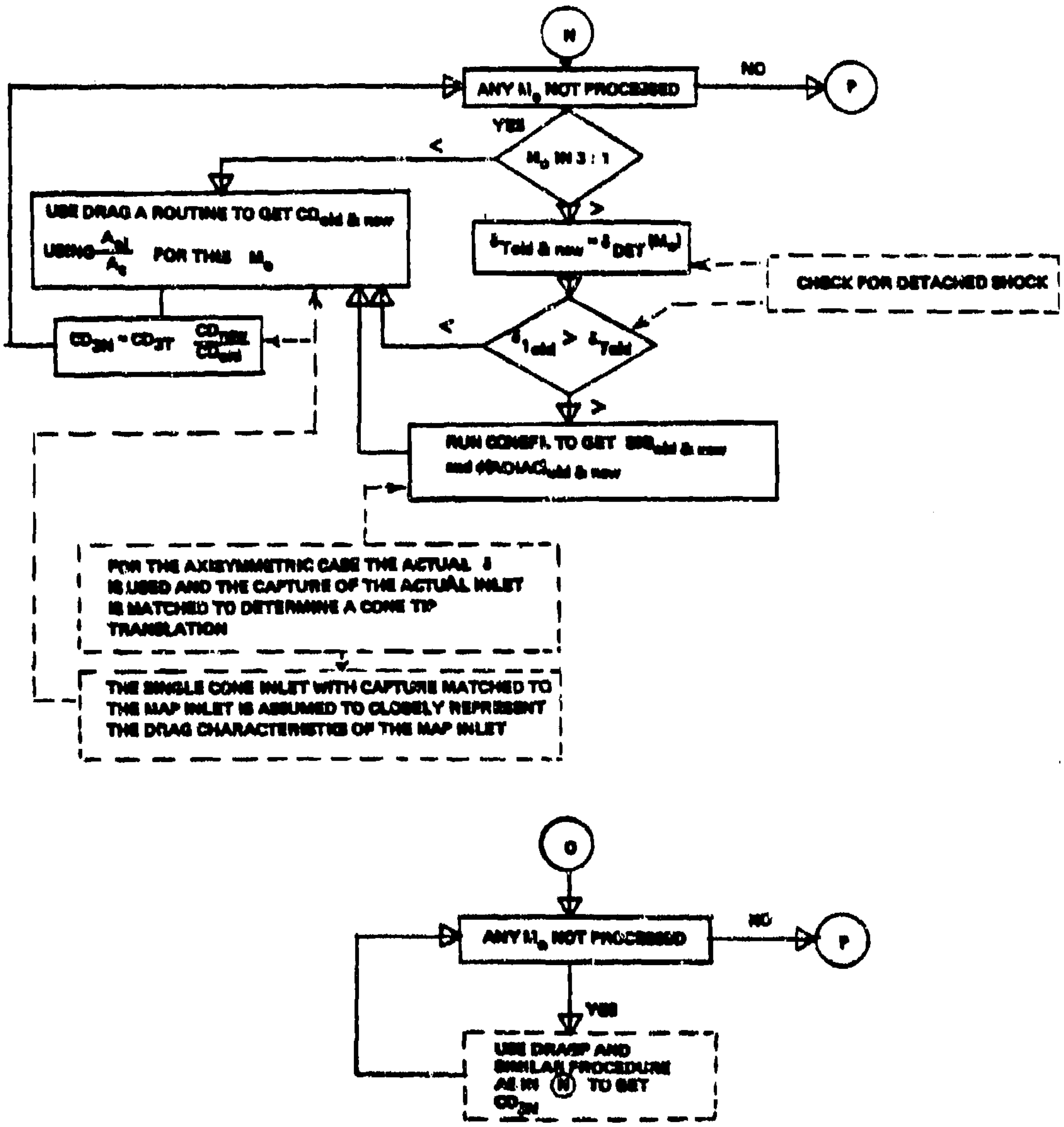


Figure 44. Flow Chart for Step 5 (cont'd)

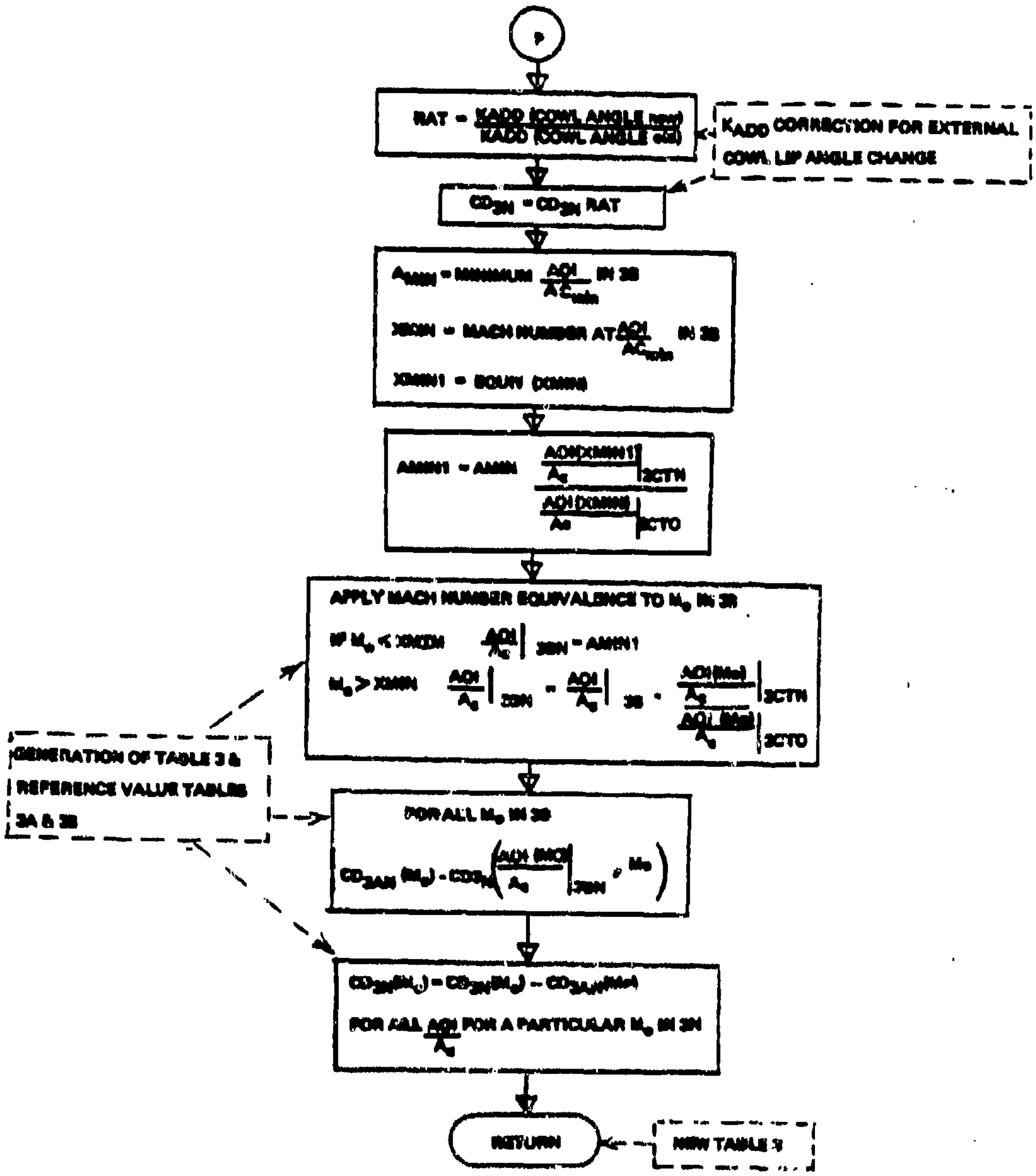


Figure 44. Flow Chart for Step 5 (concluded)

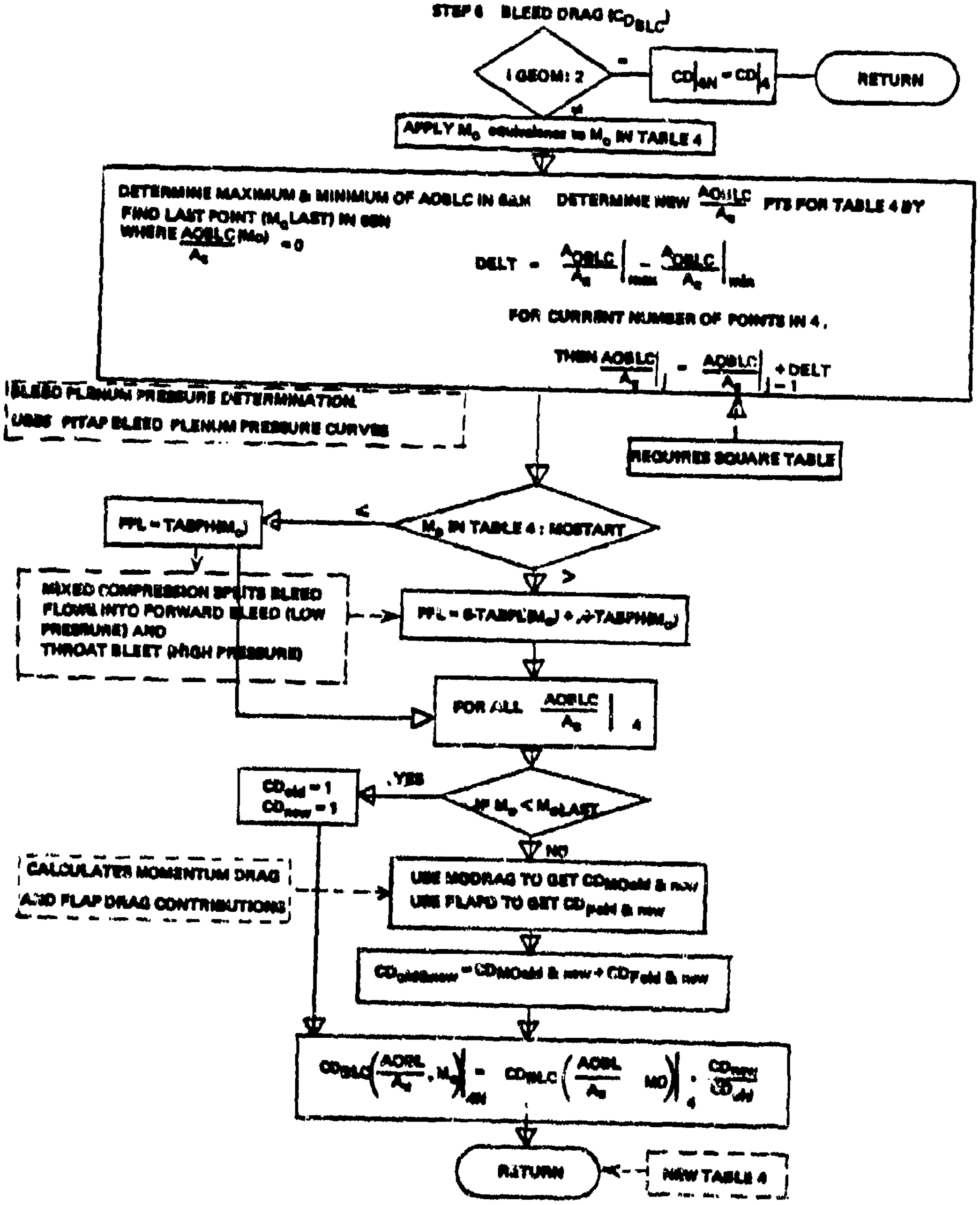


Figure 45. Flow Chart for Step 6

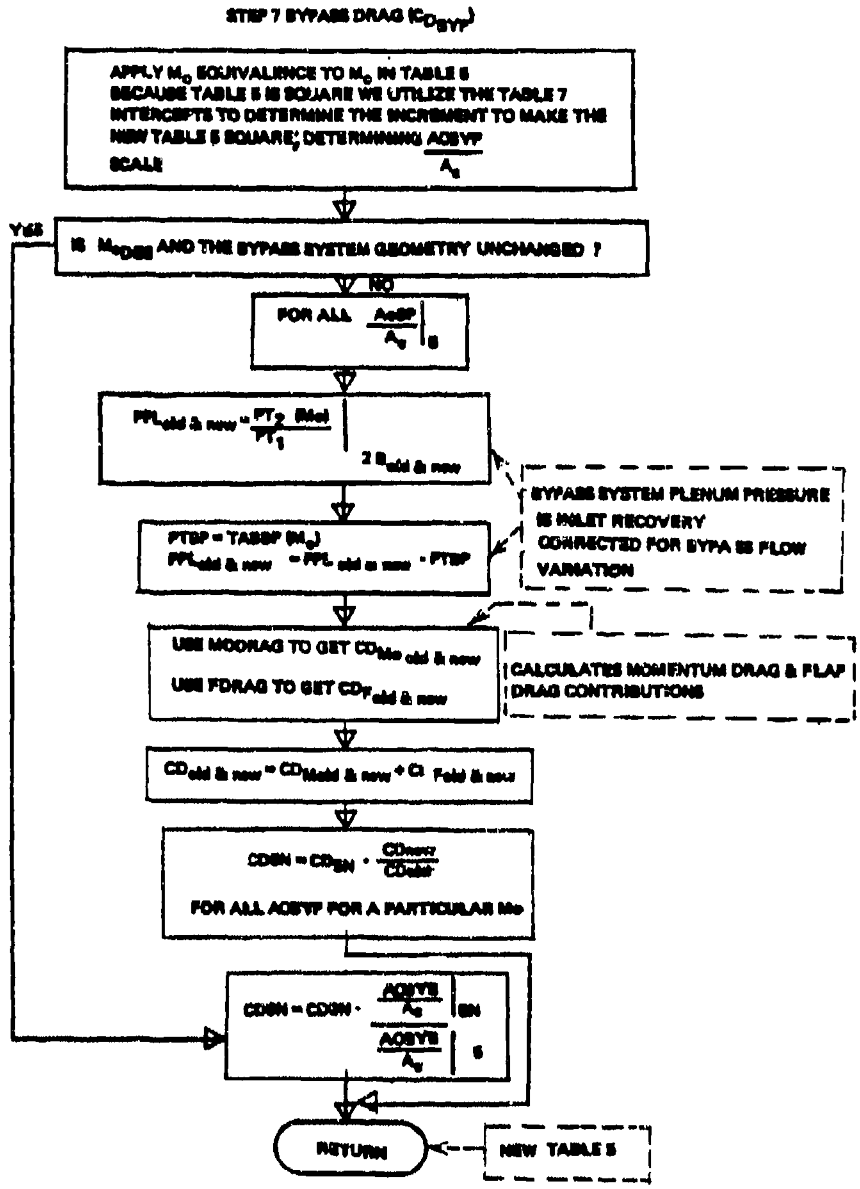


Figure 46. Flow Chart for Step 7

NOZZLE/AFTBODY DRAG DERIVATIVE PROCEDURE

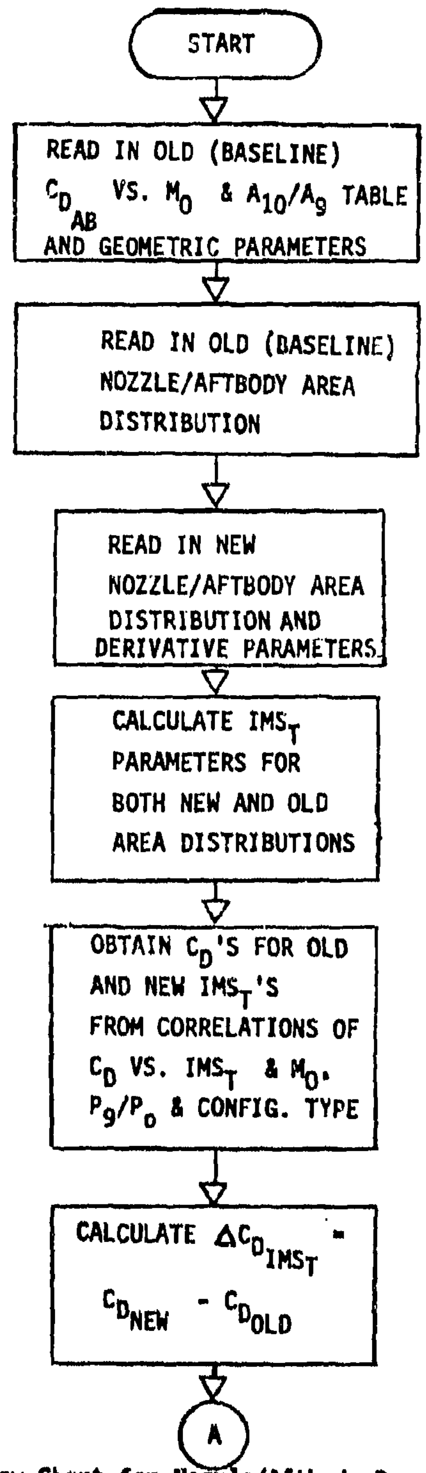


Figure 47. Flow Chart for Nozzle/Aftbody Drag Procedure

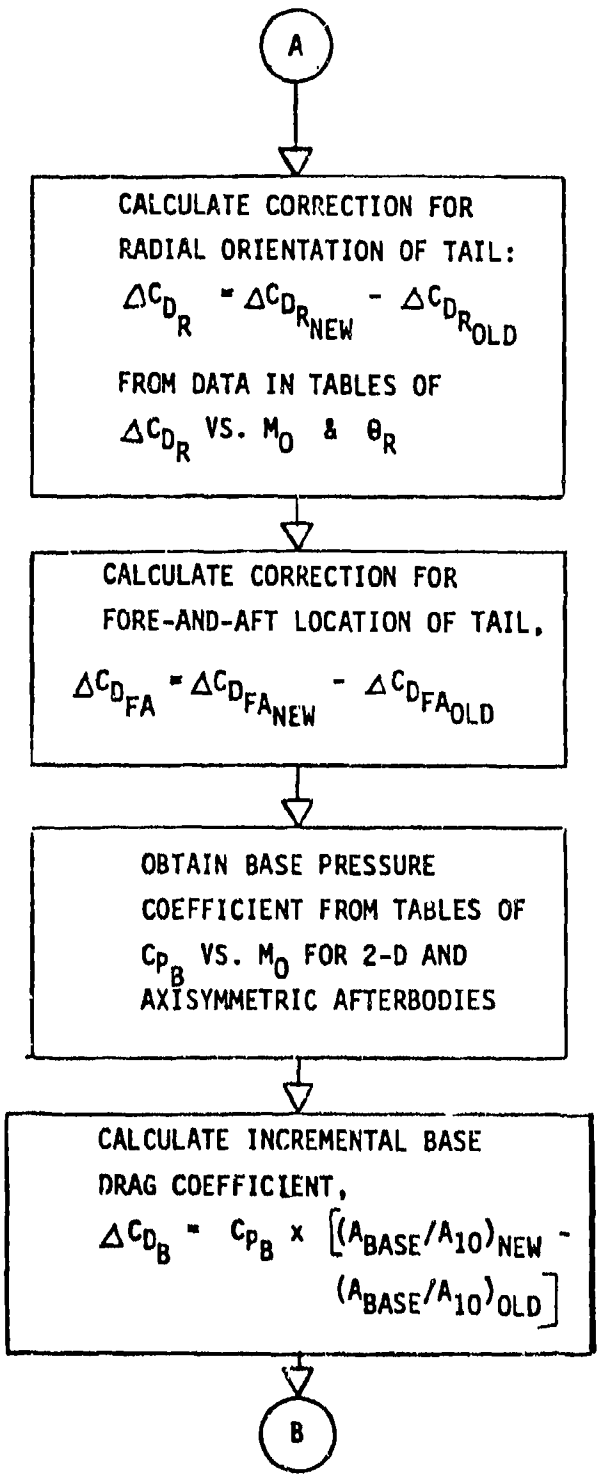
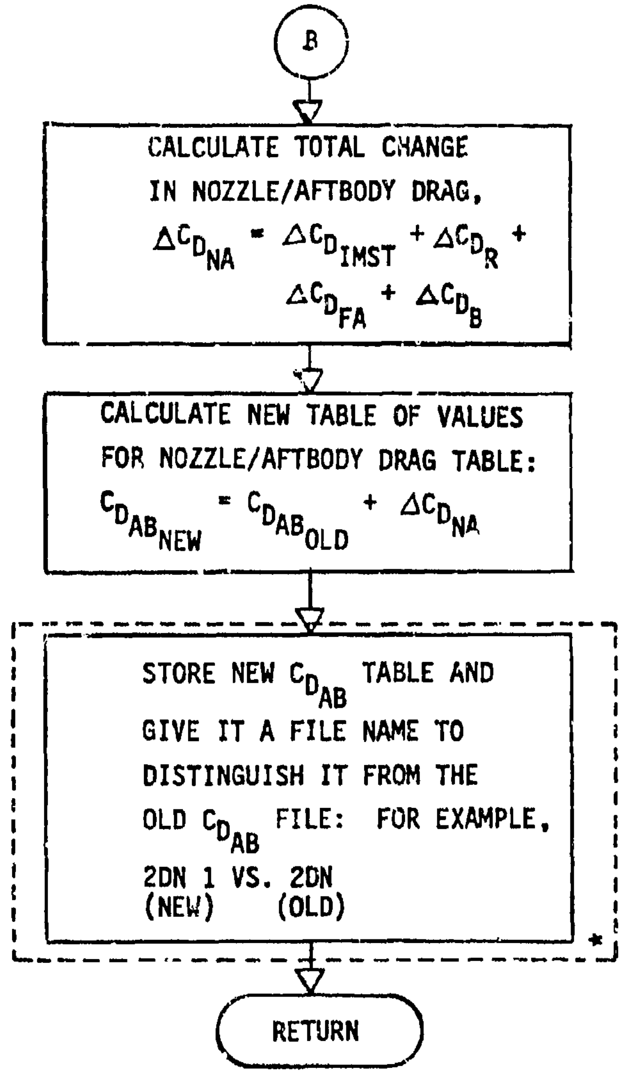


Figure 47. Flow Chart for Nozzle/Aftbody /Drag Procedure (Cont,d)



*ACCOMPLISHED EXTERNALLY TO NORMAL PROGRAM CALCULATION STEPS. SHOWN HERE FOR INFORMATION ONLY.

Figure 47. Flow Chart for Nozzle/Aftbody Drag Procedure (Concluded)

C_{F_G} FOR ROUND C-D NOZZLES

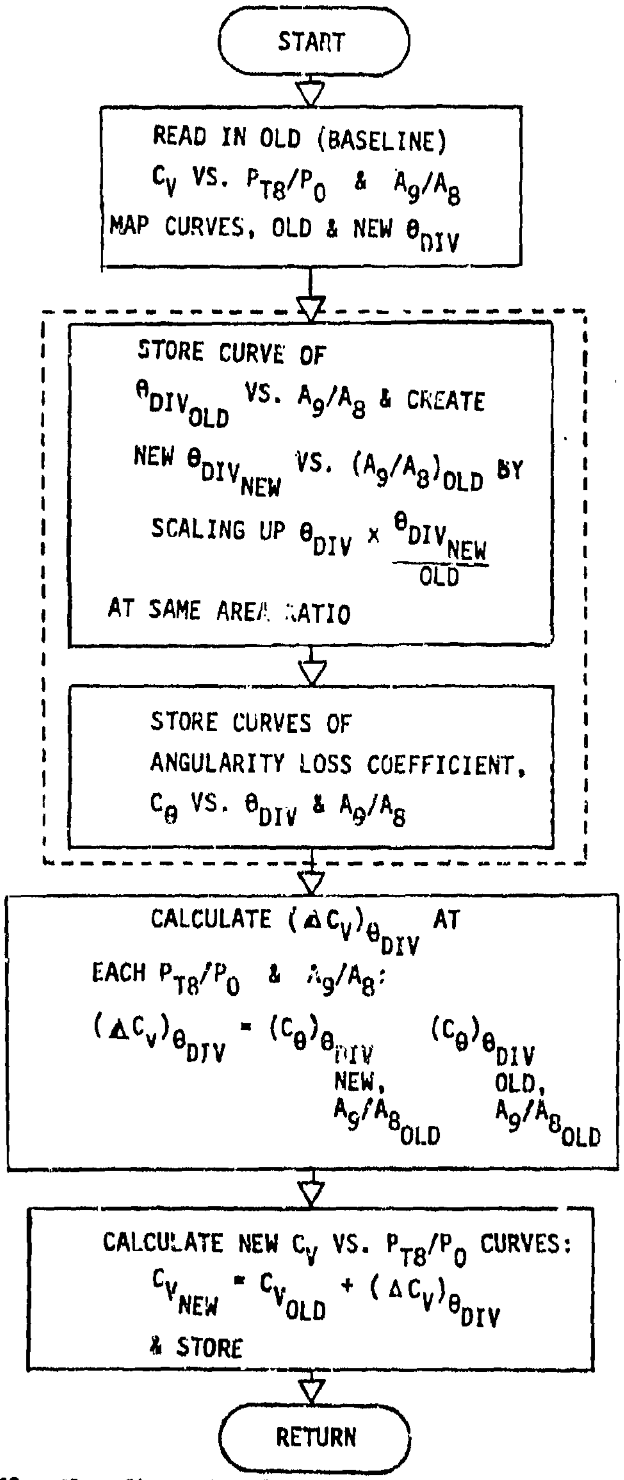


Figure 48. Flow Chart for C_{F_G} Derivative Procedure for a Round C-D Nozzle

C_{F_G} FOR ROUND PLUG NOZZLES

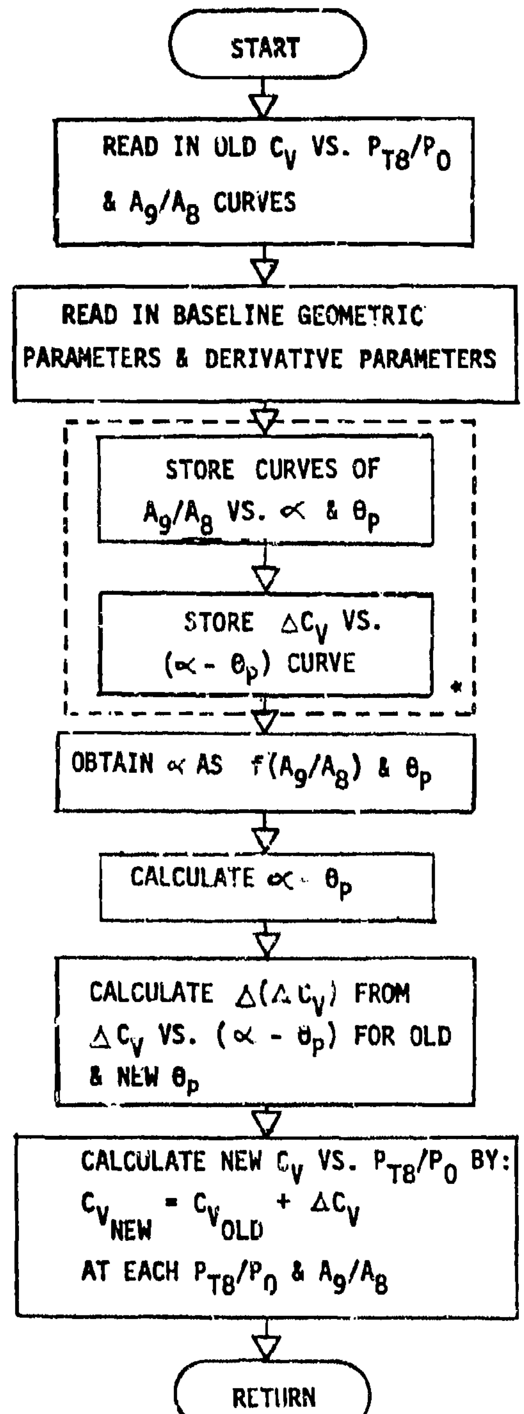


Figure 49. Flow Chart for C_{F_G} Derivative Procedure for a Round Plug Nozzle

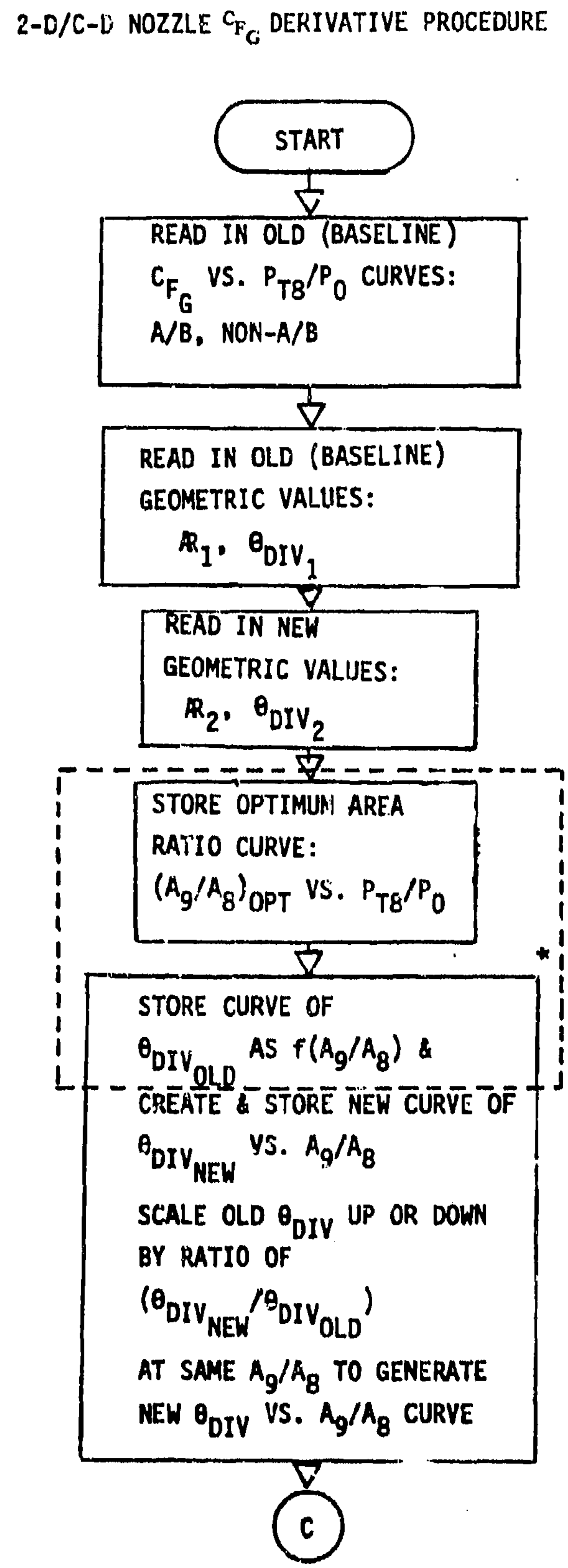


Figure 50. Flow Chart for C_{F_G} Derivative Procedure for a 2-D C-D Nozzle

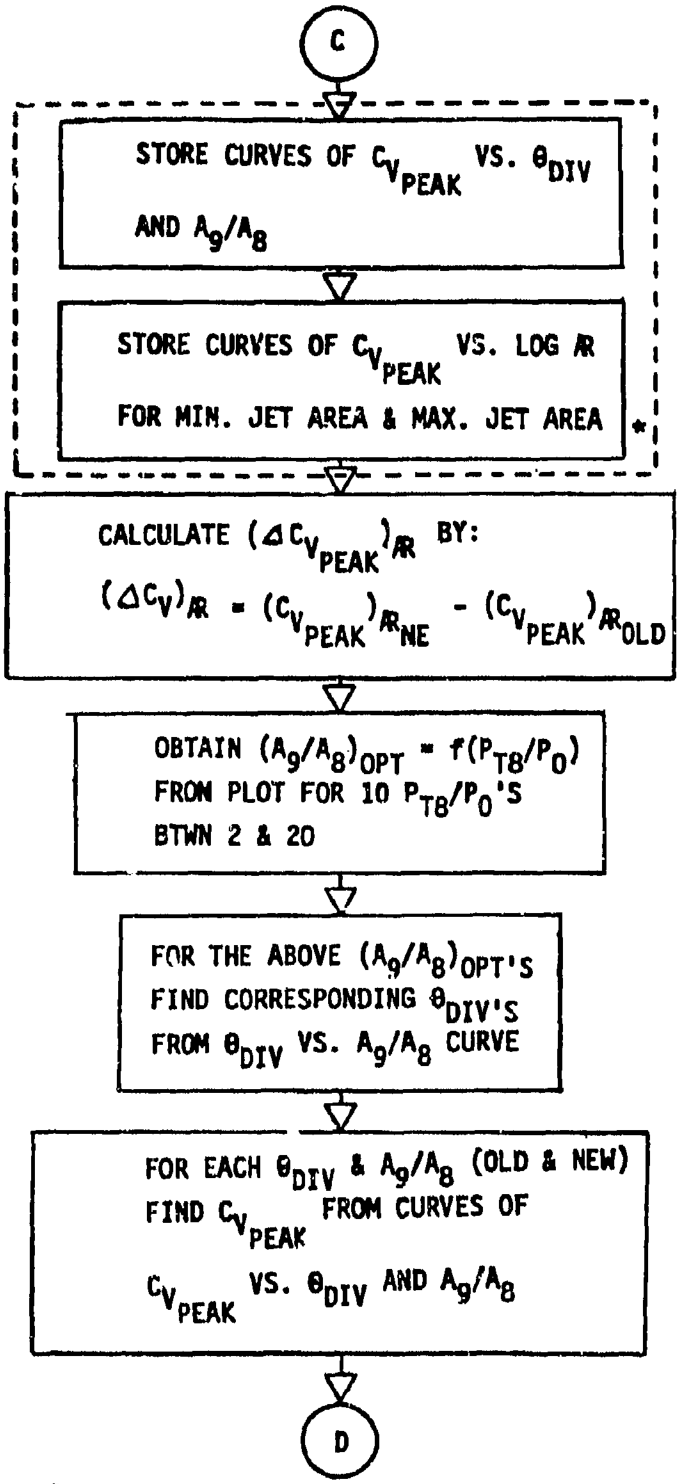


Figure 60. Flow Chart for C_{F_G} Derivative Procedure for a 2-D C-D Nozzle (Cont.d)

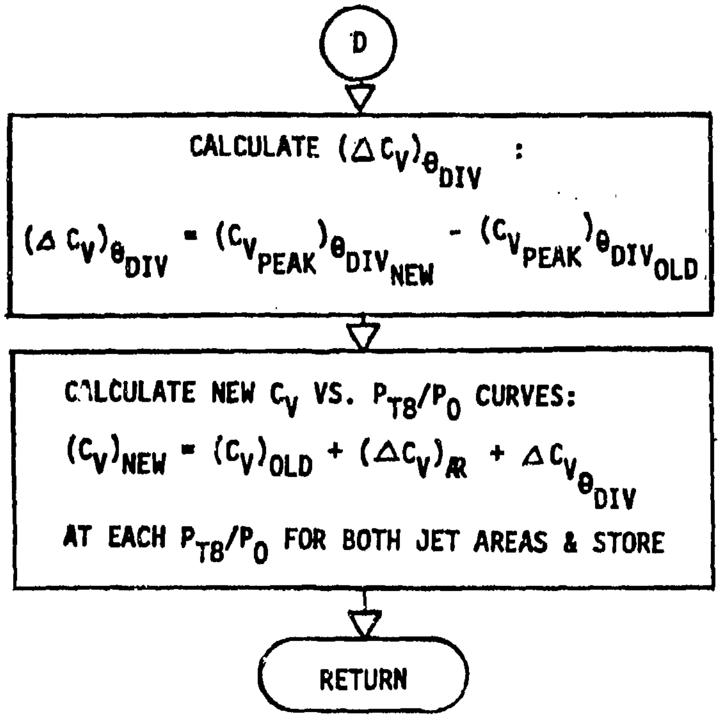
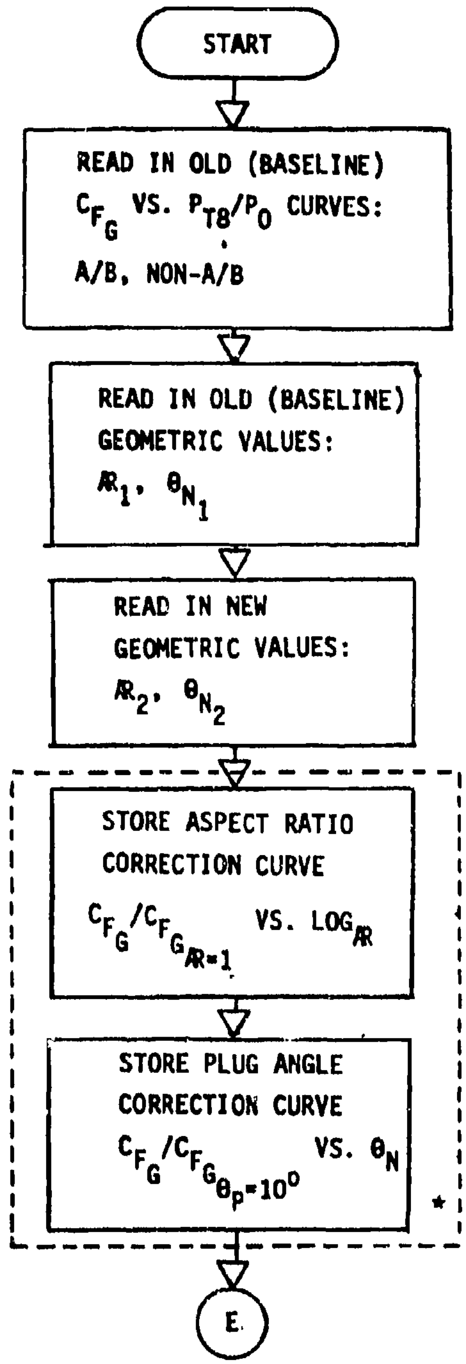


Figure 50. Flow Chart for C_{F_G} Derivative Procedure for a 2-D C-D Nozzle (Concluded)

2-D PLUG NOZZLE C_{F_G} DERIVATIVE PROCEDURE



*BUILT INTO BASIC PROGRAM.
SHOWN FOR INFORMATION ONLY.

Figure 51. Flow Chart for C_{F_G} Derivative Procedure for a 2-D Plug Nozzle

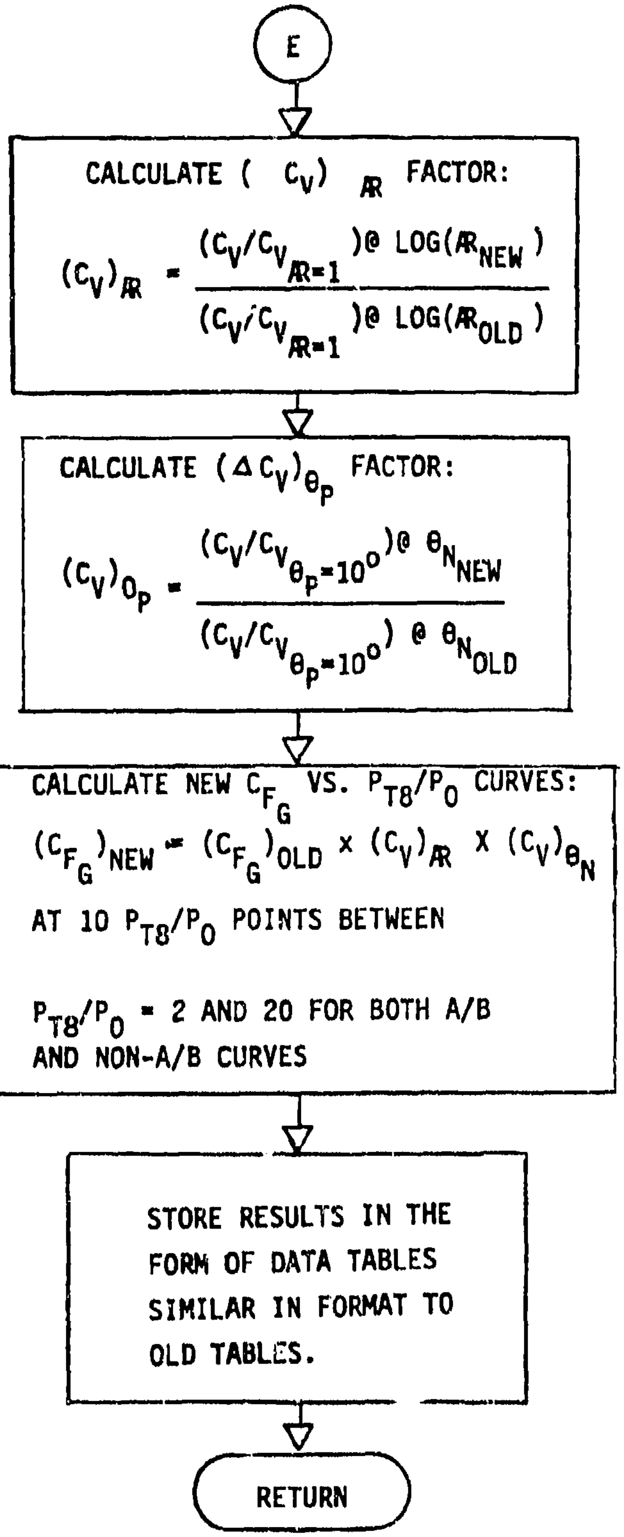


Figure 51. Flow Chart for C_{F_G} Derivative Procedure for a 2-D Plug Nozzle (Concluded)

*U.S.Government Printing Office: 1978 — 657-002/162